APPENDIX A

APPENDIX A.

Noss, R. F (1994) Translating Conservation Principles to Landscape Design for the Grasslands Water District.

Translating Conservation Principles to Landscape Design for the Grassland Water District

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INTRODUCTION

> "Although some wetlands are significantly altered or destroyed outright by a single activity during a short time period, most large wetland systems are impacted incrementally by many sources over longer periods of time." (Witmer 1985)

The wetland ecosystems of the Grasslands Management Area, known as the most valuable of the remaining wetlands in the Central Valley portion of the Pacific Flyway, are endangered by development and other human activities on surrounding and adjacent lands (Frederickson and Laubhan 1994). Like many semi-natural areas embedded in human-dominated landscapes, the Grasslands Management Area is threatened more by cumulative impacts that cross its boundaries and fragment its continuity than by outright destruction.

The values of wetlands are now generally accepted. Thus, society has afforded them some level of protection. However, the cumulative effects of diverse land-use activities on wetlands are imperceptible to most people. But they are no less real. Mitigating those impacts requires establishment of some kind of functional buffer zone between anthropogenic disturbances and natural ecosystems. It also requires that activities that might fragment wetlands and other natural or semi-natural habitats be strictly controlled, and that high levels of functional connectivity be maintained between wetlands and other areas important to wildlife.

Buffer zones and corridors are among the best accepted concepts in conservation, but a tremendous variety of buffers and linkages has been proposed. For example, in a recent review of the literature concerning riparian buffers and their functions at local scales, Johnson and Ryba (1992) observed that 38 separate investigators recommended buffer widths of 3 to 200 meters for different site-specific functions and disturbance types. On the other hand, the buffer zones recommended for national parks and other large natural areas, as in the biosphere reserve model, are often many miles in width (UNESCO 1974, Harris 1984, Noss 1987a, 1992, Hough 1988). For the Grasslands study area of approximately 179,500 acres (Frederickson and Laubhan 1994), we can assume that optimal buffer widths lie somewhere between these extremes, that is, probably more than 200 m but less than several miles. Determining optimal buffer widths and linkages to protect wetland ecosystems requires site specific review.

We examined the literature on wetland and riparian buffers and corridors with particular emphasis on issues surrounding the waterfowl habitat and the unique pressures of various land uses in the Central Valley of California. We also reviewed the general conservation biology literature related to habitat fragmentation and connectivity. Several databases were searched for relevant journal articles and technical reports: NTIS,

SELECTED WATER RESOURCES (SWRA) DATABASE, AGRICOLA, BIOLOGY & ENVIRONMENTAL SCIENCES, WILDLIFE REVIEW, BIOLOGICAL ABSTRACTS, and LIFE SCIENCES COLLECTION DATABASES. These databases were searched for keywords and subject. Keywords and phrases searched included wetland buffers, habitat buffers, waterfowl habitat, San Joaquin Valley habitat, San Joaquin wetlands, buffer width, cumulative impacts to wetlands, wildlife management, buffer characteristics, grazing and wetland/riparian, agriculture and wetland/riparian, urbanization and wetland/riparian, and others.

FRAGMENTATION OF WETLAND HABITAT AND THE NEED FOR CONNECTIVITY

The functions and features of wetlands and riparian zones overlap considerably, especially in regions such as the San Joaquin River Valley, where most wetlands are associated with riparian zones or stream systems. Characteristics of wetland/riparian areas that are vital to their habitat values for wildlife include high productivity and diversity of vegetation, early spring availability of forage for herbivores, available surface water and associated aquatic habitats, and the continuity and connectivity of these habitats that facilitates movement and migration of plants and animals (Schroeder and Allen 1992). Activities such as livestock grazing, residential development, and agricultural practices can decrease the diversity and ecological integrity of wetland communities and make them more susceptible to domination by a single vegetation type and invasion by weedy, non-native species. These changes inevitably reduce the value of the wetlands and riparian zones for native fauna and flora. Activities that fragment wetland areas make them more vulnerable to all these impacts.

Fragmentation of natural ecosystems is widely documented to have deleterious consequences. Connectivity--in many respects the opposite of fragmentation--can help keep natural ecosystems healthy in a landscape that is otherwise highly fragmented (Noss 1987b). We discuss these two topics each in turn.

Fragmentation

Fragmentation of wetland ecosystems by human activities does not differ substantially in effect from fragmemtation of other kinds of ecosystems. Habitat fragmentation is one of the greatest threats to biodiversity worldwide (Burgess and Sharpe 1981, Noss 1983, 1987a, Harris 1984, Wilcox and Murphy 1985). Fragmentation is often considered to have two components: (1) decrease in some habitat type or perhaps all natural habitat in a landscape; and (2) apportionment of the remaining habitat into smaller, more isolated pieces (Wilcove et al. 1986). Although the latter component is fragmentation per se, it usually occurs with deforestation or other massive habitat reduction (Harris 1984). An almost inevitable consequence of human settlement and resource extraction in a landscape is a patchwork of small, isolated natural areas in a sea of altered land.

Early fragmentation studies viewed the process as a species-area problem analogous to the formation of land-bridge islands as sea levels rose since the Pleistocene. Hence, island biogeographic theory (MacArthur and Wilson 1963, 1967) was invoked to explain losses of species as the area of habitats declined and their isolation increased. Certainly, there are good analogies between real islands and caves, lakes, prairies in a forested landscape, or pieces of remnant forest in agricultural land. But there are differences, too. The water that surrounds real islands provides habitat for few terrestrial species. In contrast, the matrix surrounding habitat islands may be a rich source of colonists to the island, many of which are invasive, exotic weeds or predators on species inhabiting the island. Remnant wetlands are especially susceptible to exotic species invasion in fragmented landscapes (Ehrenfeld 1983).

Species richness does not always decline on isolated habitat patches, as predicted by island biogeographic theory. Richness may even increase (at least temporarily) as species invade from adjacent disturbed areas. In such a case, species composition often shifts toward weedy, opportunistic species while sensitive species of habitat interiors are lost (Noss 1983, Lynch 1987). The matrix in a fragmented landscape is also in a state of flux, as crops are planted and harvested, as tree plantations go through their rotations, as farming or silvicultural methods change, and as human settlements grow and decline. Thus the external environment of a habitat patch is not as constant or predictable as the water surrounding a real island.

Fragmentation is a process and ecological effects will change as the process unfolds (Wiens 1989). In the early stages of the process, the original landscape is perforated by human-created openings of various sizes, but the matrix remains natural habitat. At this stage, we would expect the abundance of native species of the original landscape to be affected little, although the access created by human trails or roads may reduce or extirpate large carnivores, furbearers, and other species subject to human exploitation or persecution. Such losses are well documented historically. Also, a narrow endemic species whose sole habitat just happened to be in an area converted to human land use would also be lost. As human activity increases in the landscape, the gaps in the original matrix become larger, more numerous, or both, until eventually they occupy more than half of the landscape and therefore become the matrix. A highly fragmented landscape may consist of a few remnant patches of natural habitat in a sea of converted land. Many landscapes around the world have followed this pattern of change (Noss and Csuti 1994).

Fragmentation does not necessarily spell extinction. A species might persist in a highly fragmented landscape in three ways (Noss and Csuti 1994). First, it might be able to survive or even thrive in the matrix of human land use. A number of weedy plants, insects, fungi, microbes, and vertebrates such as European starlings and house mice fit this description. Second, it might be able to maintain viable populations within individual habitat fragments; this is an option only for plants, microbes, and small-bodied animals with modest area requirements. Or third, it might be highly mobile. A mobile species could integrate a number of habitat patches, either into individual home ranges or into an interbreeding population. Pileated woodpeckers, for example, have learned to fly among a number of small woodlots to forage in landscapes that were formerly continuous forest (Whitcomb et al 1981, Merriam 1991). A species incapable of pursuing one or more of these three options is bound for eventual extinction in a fragmented landscape.

Besides the problem of small populations in small habitat patches being more likely to go extinct, small patches are also greatly affected by their surroundings. Sun, wind, rain, and other physical factors create a different environment near the edges of a habitat patch from in the interior, particularly for forests with relatively closed canopies. Predators, competitors, and parasites may also thrive in the disturbed habitat near an edge and penetrate some distance into the patch. Studies of birds in several regions of North America have documented increased rates of nest predation and brood parasitism by brown-headed cowbirds in forest, grassland, and wetland ecosystems fragmented by human activities

(Whitcomb et al. 1981, Brittinghman and Temple 1983, Noss 1983, 1987a, Harris 1984, Wilcove et al. 1986, Harris and Silva-Lopez 1992, Noss and Csuti 1994). Deleterious edge effects commonly extend 50-200 m into a habitat from an edge, and in some cases much farther (Noss 1983, Wilcove et al. 1986, Noss and Cooperrider 1994).

The kind of fragmentation that poses the most immediate threat in the Grasslands Management Area is development activities (for example, intensification of agriculture, housing or golf course development) that create movement barriers between units of habitat used by wildlife. As noted by Frederickson and Laubhan (1994, p. 59). "clearly species with large home ranges have very few areas of suitable size for survival. Thus, a few additional activities resulting in fragmentation will impact many more species." For example, the north and south units of the Grasslands are separated by Highway 152. Roads are known to be movement barriers to many species of small animals (see review in Noss 1993 and Noss and Cooperrider 1994). Thus, the road already fragments the wetland ecosystem. However, a small strip of habitat adjacent to Mud Slough may provide a corridor (or, more accurately, a bottleneck in a natural corridor) along which some species will travel. Aquatic species will move along Mud Slough itself. The agricultural fields to the north of the highway are probably also used as travel routes for species such as the giant garter snake (Thamnophis gigas; many records of this species in this area are in the California Natural Diversity Data Base), though they are not suitable breeding habitat.

Any further fragmentation of this vulnerable linkage between the north and south units of the Grasslands Management Area could well provide the "final blow" in fragmenting the wetland ecosystem. Importantly, fragmentation is not a black-and-white, "either-or" situation. Rather, it is a relative and cumulative problem. After some threshold of fragmentation is exceeded, movement of individuals will no longer occur regularly enough to maintain the population of a fragmentation-sensitive species. Until detailed, long-term studies of species in the study area are performed, the prudent course is to prevent any further fragmentation of the system. Indeed, professional opinion among scientists is now firm that the burden of proof in such matters must rest on those who propose activities that may fragment or otherwise degrade ecosystems.

In addition to the many negative effects of fragmentation, as documented in various habitats around the world, wetland ecosystems are likely to suffer from disruptions of water flow and other hydrological impacts that accompany fragmentation. For example, drainage canals, dikes, and roads have had severe effects on the hydrology, vegetation, flora, and fauna of the Everglades (Kushlan 1979). Similarly, fragmentation has altered flow patterns and other aspects of hydrology in the Grasslands study area, but in ways that have not been well documented (Frederickson and Laubhan 1994).

Connectivity

Connectivity--or, in particular, corridors--is a complex and contentious issue among conservation biologists (Noss 1987b, Simberloff and Cox 1987, Hobbs 1992, Simberloff et al. 1992, Noss 1993). What conservation biologists are interested in is not simply some corridor we can recognize in the landscape or draw on a map, but rather functional connectivity. Functional connectivity is usually measured according to the potential for movement and population interchange of a target species. The degree of functional connectivity in a landscape or reserve network is influenced by many factors (Table 1; Noss and Cooperrider 1994).

Connectivity is not just corridors. For species that disperse in apparently random directions, such as the northern spotted owl (Thomas et al. 1990), connectivity is affected more by the suitability of the overall landscape matrix than by the presence or absence of discrete corridors. Also, not all linkages are functionally equivalent; some, such as narrow edge-dominated corridors, may do more harm than good by serving as mortality sinks (Henein and Merriam 1990). Some kinds of corridors (for example, roadsides) also create conservation problems, such as by facilitating the spread of weedy and exotic species (Noss 1993a). But other corridors, for example, riparian systems, are well accepted as critical movement routes for many wildlife species (Harris 1984, Noss and Harris 1986, Binford and Buchenau 1983).

Viewed from the perspective of land-use planning, connectivity is basically the opposite of fragmentation. In contrast to breaking landscapes into pieces, we seek ways to preserve existing connections and restore severed connections. Preserving existing connections is almost always a good idea. As argued by Hobbs (1992), "maintenance of existing linkages should be an important component of any conservation plan, on the basis that it is easier to retain them now than to replace them in the future." Thus, as noted above, in the absence of data to the contrary, the most prudent and conservative planning decision is to prohibit any further fragmentation of an ecosystem and maintain existing levels of connectivity.

Specifying the scale of connectivity being considered in a conservation plan is critical; the spatial scale would vary depending on the scale at which the target species disperse and travel about the landscape. Narrow fencerow corridors a few hundred feet in length form an appropriate scale for considering functional connectivity for rodent populations (Merriam 1988), whereas a multiple-use landscape 30 miles wide that lies between two national parks can be considered a corridor at a regional scale, if it functions as such for wide-ranging animals (Noss 1992).

Thus, linkages within the Grasslands Water District--such as the narrow corridor connecting the north and south units--are important to wildlife at a relatively fine scale determined by local population dynamics. The connectivity of the Grasslands within the system of natural and semi-natural habitats in the San Joaquin Valley and the entire Central Valley is important at a broader scale, as determined by movements of wider-ranging or migratory species. Finally, the role of remnant wetlands of the Central Valley in the Pacific Flyway corridor is critical at a still broader scale for migratory waterfowl (Frederickson and Laubhan 1994).

In landscapes where natural corridors have been destroyed and cannot easily be restored, reserves should ideally be very close together and not separated by insurmountable barriers (Diamond 1975, Thomas et al. 1990). For species, such as many small vertebrates and flightless invertebrates, that refuse to cross roads or other relatively narrow swaths of unsuitable habitat (Oxley et al. 1974, Mader 1984, Swihart and Slade 1984, Mader et al. 1990), continuous habitat linkages are needed both for movements within home ranges and for dispersal. In many cases, roads have been elevated (i.e., underpasses or tunnels created) to allow passage of wildlife underneath (Noss 1993).

Even in the absence of distinct movement barriers, sheer distance can make successful dispersal unlikely, even for species as mobile as large mammals. Thus, reserves separated by areas of unsuitable habitat longer than normal (mean or median) dispersal distances of target species should contain resident individuals or populations between them, either distributed more or less continuously or in stepping stone habitats.

Applying basic principles of conservation biology design and considering the importance of connectivity, a reserve design model for a human-dominated region consists of core reserves linked by corridors of suitable habitat and enveloped by buffer zones (Fig. 1, adapted from Noss 1992). Riparian systems are natural candidates for corridors, as they constiture paths of least resistance through many landscapes and are often used as movement routes by wildlife (Noss and Harris 1986, Binford and Buchenau 1993). Regional networks of two or more reserves might be linked to other regions by corridors established along rivers, ridgelines, or other functionally significant natural features (Noss 1992, 1993).

As noted above, in the Grasslands Management Area the natural linkage between the north and south units has been partially severed by Highway 152; Highway 165 partially fragments the north unit (Frederickson and Laubhan 1994). Canals and other human-disturbed habitats further subdivide the area for many species. The effects of these barriers on the functional connectivity of the Grasslands for various species has not been well documented. However, a functional corridor still exists between the north and south units for many species of animals. Unfortunately, detailed data on use of this corridor by various animal species do not exist. Again, in the absence of specific data on corridor use, the prudent option is to maintain existing linkages (Noss 1987b, 1993, Hobbs 1992). Maintaining and enhancing the corridor between the north and south units of the Grassland Management Area is one of the highest priorities in managing the ecosystem.

EFFECTS OF ADJACENT LAND USES ON WETLANDS AND THEIR FUNCTIONS

The effects of land use activities on wetland systems are multiple. The problem is compounded by the cumulative nature of many pressures that are difficult to comprehend without viewing the whole picture. Agriculture currently affects more wetland area nationally than any other human activity. In the context of cumulative impacts, the major dangers to wetlands are agricultural development, urban development, and conversion of wetlands to deep water habitats. However, urbanization is rapidly increasing in importance as an impact, and most studies suggest that the effects of urbanization on a given wetland are more severe than the effects of agriculture.

Effects of livestock grazing and agriculture

Agricultural activities, including livestock grazing, affect more wetland area than any other land use in the United States (Nelson 1989). The most prevalent abuse of wetland/riparian zones in many regions is livestock grazing (White 1991). Cattle and sheep are attracted to wetland and riparian zones because of the quality of vegetation, the shade provided in such areas, and the availability of water. Grazing affects many elements of the wetland ecosystem. In general, impacts to wetland vegetation can be separated into four areas: compaction of soils (which increases runoff and decreases water availability to plants), herbage removal, physical damage to vegetation by rubbing, trampling, and browsing, and changes in the fluvial processes, which may lower the water table and cause a decline in the vegetation that thrives in wetland conditions (Kauffman 1988). Over grazing not only affects the vegetative component of the wetland, but can also increase soil erosion and alter hydrology. Like most other impacts from various land uses, the effects of grazing cascade to affect other elements of the system and reduce the overall functions and values of wetlands.

In a study of riparian habitat in western Texas, Schmidly and Ditton (1978) documented a significant difference in species composition and density of mammals between grazed and ungrazed sites. For example, the rodent fauna under grazing conditions was composed primarily of heteromyid rodents (66% of total catch) whereas representatives of this family of rodents were rare on the ungrazed sites (1.4% of the total catch).

The effects of grazing on wildlife and other ecological values in the Grasslands Water District have not been well studied. Certainly it would not be wise to intensify grazing in areas adjacent to wetlands. In many areas, reduction in grazing pressure may be required, but research is needed to determine the optimal level.

Row and truck crop agriculture also have effects on adjacent wetlands. Reduction of water quality in riverine and wetland systems is often associated with run-off from farms (Bingham et al. 1980). Agricultural run-off affects habitat structure and diversity and reduces populations of sensitive species. As Heitmeyer et al (1989) suggested, increased toxic contamination of invertebrates and seeds in wetlands may have been partly responsible for waterfowl population declines in the San Joaquin Valley. These results suggest that maintenance of healthy waterfowl populations may require either a reduction in the total amount of land devoted to agriculture in the valley, restrictions on agricultural use of pesticides and other chemicals, or both. However, an undeveloped upland buffer zone of sufficient width might help reduce flow of chemicals into the wetlands.

Between 1950 and 1970, conversion to agriculture was by far the major cause of palustrine wetland loss nationwide (Dahl 1990, Johnston 1994). Nearly 50% of mature riparian vegetation in the Sacramento River Valley was removed and converted to agriculture between 1952 and 1972 (Burns 1978). Other impacts include the increase in relative corridor length between wetlands as wetland density decreases in a valley. Johnston (1994) states that increased corridor length could have a cumulative effect and "could be detrimental to animals that traverse over non-wetland areas to use the resources of several wetlands, the increased travel length putting them at greater risk to predation by humans and other animals."

Farming in North America has a significant impact on nesting and brood rearing waterfowl (Kadlec and Smith 1992). Agriculture is in direct competition for "wet soils" that would normally be utilized by waterfowl. In addition to the destruction of wetlands and waterfowl habitat for agricultural use, the erosion and pollutant runoff associated with cultivated farming adversely effects waterfowl and wetlands in general.

Despite the documented damage that agricultural activities cause to wetlands, low-intensity agriculture certainly causes less harm than intensive agriculture. Conservation easements and other mechanisms that improve the buffering capacity of farmlands and increase their value to wildlife should be sought in the Grasslands sudy area.

Urban development

Urban development is widely regarded to be the land use with greatest potential impacts to wetlands (Cooke 1992). A study of wetlands in the Puget Sound area determined that the degree of urbanization surrounding a wetland is strongly correlated with the degree of disturbance to the wetland (Cooke and Conneley 1990, Cooke 1992). The more developed the basin in which a wetland complex exists, the more potential deleterious impacts there are to the wetland (Ehrenfeld 1983, Cooke 1992). Thus, wetland conservation programs must not only consider protection of individual wetlands, but must also control the extent of development throughout the watershed or landscape in which wetlands exist.

Impacts of urban development on wetlands noted in the Puget Sound study (Cooke 1992) include (1) physical disruption, such as mowing and digging; (2) chemical disruption, including inputs of toxicants and fertilizers from lawns and roads; (3) competitive disruption from introduction of nonnative species; (4) noise disruption, for example from roads and lawnmowers; and (5) visible disruption, for instance removing the tree and shrub canopy that screens wetlands. Cooke (1992) found that buffer zone functions were reduced in direct proportion to the narrowness of the buffer. Buffers less than 50 feet wide showed a 90% increase in degradation after adjacent urbanization.

In a study of wetlands affected by development as compared to pristine sites, Ehrenfeld (1983) found that the developed sites tended to lose the herbaceous species component and exhibitied a decreased frequency of shrub species. This vegetation was replaced by species from surrounding geographic regions and exotics, a large number of which were vines. The resulting areas exhibited low habitat value and were degraded because of the exotic and weedy nature of the colonizers. Urbanization changed water chemistry and flow, and drastically altered the plant and animal communities of the wetlands. "One of the most important environmental changes (in wetlands draining developed lands) is the addition of nutrients to the nutrient poor ground and surface water as a result of urbanization" (Ehrenfeld 1983).

Because urbanization usually seems to cause more damage to adjacent wetlands than do other land uses, maintenance of a buffer zone (even if in agriculture, rather than natural habitat) between urban areas and wetlands is essential. Cooke (1992) found that the effectiveness of buffers in protecting adjacent wetlands depends on (1) the number of lots adjacent to the buffer (the fewer, the better); (2) the size of the buffer (the wider, the better); (3) the type of buffer (vegetation types that act as visual screens, physical barriers to humans, sediment filters, and chemical filters are preferred); and (4) ownership of the buffer (buffers owned by landowners who appreciate the purpose of the buffer remain more intact).

Wetland buffers and their characteristics

Wetland scientists generally agree that buffers are needed to protect wetland habitats. Wetland buffers not only have the potential to insulate wetlands from adverse effects of various land use activities, but in many instances they also form unique and valuable habitat in their own right (Brown et al. 1987).

Our examination of the Grasslands Management Area suggests that the buffer concept be viewed holistically. Among the potential functions of buffer zones are the following:

1. Capture key ecological factors (rare species occurrences, key watersheds, etc.) not included in core reserve due to financial, political, or other limitations. Ideally the most valuable sites are encompassed in the core reserve, but buffer zones might include areas of somewhat lesser value (less concentrated rare species occurrences, higher road density, greater past disturbance by humans, etc.).

2. Provide supplemental habitat (for instance, for foraging) for key species inhabiting the core reserve.

3. Serve as a true buffer or filter that protects sensitive habitats and species in core reserve from disruptive human influences and edge effects originating in the surrounding matrix.

4. Protect people and their domestic animals and plants from depredating large mammals that may reach relatively high densities in core reserves.

5. Serve as suitable and safe movement habitat for animals traveling between and among core reserves.

6. Serve as areas for developing, testing, and demonstrating land-use and management practices that are compatible with conservation of biodiversity.

Buffer zones should be as wide as necessary to accomplish these objectives, or at least some subset of them. Necessary width will vary depending on several factors:

a. Size of reserve. The relationship is usually inverse, in that very large reserves may not require buffer zones, whereas small reserves are subject to intense edge effects and need buffering.

b. Type and intensity of land use in matrix. For example, a wider buffer zone is indicated if the matrix is high-density residential as opposed to agricultural land-use.

c. Types and intensities of use expected in buffer zone. If hunting, for example, is expected to be intense in the buffer zone and species sensitive to hunting occur there, the zone should be wide enough that hunters do not penetrate far into the zone from access points along its periphery.

Two or more buffer zones may be advisable in some cases, with inner zones more strictly protected (e.g., lower road density, more restrictions on agrilcultural activities) than outer zones. This is the multiple-use module idea of Harris (1984; see also Noss and Harris 1986, Noss 1987b).

The width of buffer zone needed to protect wetlands is not easy to determine and must involve site-specific analysis. Since different wetlands have different values that people choose to protect, there is great variance in the proposed buffer width among wetlands and types of disturbance. Buffer zones must remain relatively intact for a long time to function effectively (Corbett and Lynch 1985).

The most common buffer widths that have been recommended for riparian systems are from 12 to 33 meters (40-100 feet) (Corbett and Lynch 1985). Wetland/riparian buffer widths of 33 meters (100 feet) or greater may be effective in maintaining water quality depending on the disturbance types in surrounding areas (Castelle et al. 1992).

However, recent research indicates that many buffers are too narrow to protect wetlands and aquatic habitats (Binford and Buchenau 1993). In King County, Washington, the 7.6 meter (25 foot) buffers commonly established around wetlands in urban settings failed to prevent degradation of wetlands (Cooke 1992). Significant deposition of sediments eroded from agricultural fields in Maryland occurred 80 meters from a field into a riparian forest (Lowrance et al. 1988). Based on her study of wetlands in the New Jersey Pine Barrens, Ehrenfeld (1983) was convinced of the degrading effect of urbanized runoff, but saw the need for more research to determine whether conventional buffers are sufficient to prevent degradation of the wetlands. In their review of riparian corridors, Binford and Buchenau (1993) conclude that "80 to 100 meters would be a reasonable minimum range of buffer widths...if the objective were to reduce sediment load by 50 to 75 percent; wider corridors would be necessary for greater sediment removal."

As waterfowl habitats, wetland buffers should provide waterfowl nesting sites and food, and should meet behavioral requirements such as visual isolation and cover in proper configurations to avoid or reduce predation. As Kadlec and Smith (1992) note, a single vegetation type is not likely to provide the diverse habitats required by different species of waterfowl. "In describing optimum riparian habitat, we must recognize that what is optimum nesting habitat for a mallard (*Anas platyrhynchos*) is totally unacceptable for a killdeer (*Charadrius vociferus*)" (Kauffman, 1988). Hence there is a definite need for structural as well as community diversity of wetlands and their associated buffers. Habitat components that can be provided by buffers include plant species diversity, structural complexity, and shelter. Buffers can provide cover and nesting sites for those species that utilize a mix of wetland and upland areas.

In a study of Central Valley habitats, Hehnke and Stone (1978) observed that in spring and fall migrations, bird density and diversity were higher in riparian and associated vegetation than in riprapped slopes. In the same study, about 85% of the total number of birds using agricultural land were blackbirds and sparrows, which indicate a disturbed and impoverished community. Riparian vegetation appears to be the major factor controlling avian diversity and density in the Sacramento Basin. Wetlands and their associated buffers need to be productive enough to provide the 750-950 kg/ha of food necessary to support current waterfowl populations. There is some question whether the wetland resources of the Central Valley can sustain these needs (Heitmeyer et al. 1989). If riparian and wetland vegetation in the Central Valley is further modified, plant and animal diversity can be expected to decline.

Wetland size is an important factor for many species. However, wetlands of relatively small size can be useful to waterfowl and some other animal species if they are well buffered and connected to other wetlands. Sousa and Farmer (1983) estimated that the minimum habitat area for wood duck broods is about 10 acres. Wetlands smaller than 10 acres may be used when they are not isolated from other wetlands (i.e., as long as they are connected by buffered corridors). Wood ducks nest in tree cavities and need 20 acres of nesting habitat for each acre of brood rearing habitat. Sousa and Farmer (1983) suggested that buffers be established in relation to open water, specifically in a ratio 50-75% cover to 25-50% open water.

Studies of wildlife habitat use along wetland-upland ecotones provide additional guidance for buffer zone width. To maintain waterfowl habitat in wetland areas, Castelle et al. (1992) recognized the need to retain natural vegetation structure in an upland buffer extending out 182 meters (600 feet) from a wetland. In a study of wood ducks in Washington, nests were located from 0 to 350 meters (0 to 1149 feet) from open water; most were within 182 meters (600 feet) of open water (Milligan 1985). Optimum nest cover values are assumed to occur within the first 250 meters from any given wetland (Milligan 1985). In a survey of Swainson's hawks in the Central Valley, Schlorff and Bloom (1984) found that 77% of the nesting territories that they surveyed were within 432 meters (1,500 feet) of riparian and wetland areas and were often found in valley oak (*Quercus lobata*) and Fremont cottonwoods (*Populus fremontii*) that averaged at least 12 meters in height.

An important function of buffer zones is to help insulate sensitive animals from human activity. Josselyn et al. (1989) noted that human activity within 53 meters (175 feet) of different waterbirds could disturb them and cause an evasive response. Buffers composed of high vegetation (2-3 meters) were noted to be moderately to highly effective. Aquatic species are also sensitive to anthropogenic disturbance. Studies of invertebrate interactions within wetland and riparian zones in California suggest that buffers of at least 30 meters are needed to protect the benthic community from impacts associated with timber harvesting (Newbold et al. 1980). Eng (1984) noted that broad habitat protection is more effective that single-species conservation programs for endangered, threatened, and rare invertebrates in California.

Finally, the total width of riparian vegetation retained is an important consideration, because many animal species associated with these communities are area- or edge-sensitive. For example, avian use of riparian and wetland corridors varies with corridor width. On the basis of bird population studies in Maryland and Delaware, Keller et al. (1993) recommended that riparian forests should be at least 100 meters wide to provide some nesting habitat for area-sensitive species.

These studies indicate that conventional, narrow buffer zones for wetlands are usually ineffective, and that wider zones of at least 100 meters are needed to meet minimal wildlife needs. However, even these widths assume that the buffer is in ideal natural habitat. Buffers degraded to some degree, such as by agricultural activity, probably need to be much wider. The extremely wide buffer zones (several miles) recommended for biosphere reserves (e.g., UNESCO 1974) are intended in part to serve as areas for demonstrating land-use practices and lifestyles that are compatible with biodiversity. Such a purpose would also seem appropriate for the lands surrounding the Grasslands Management Area.

Recommendation

Because most of the habitat bordering the Grasslands Management Area is currently in agricultural use, we can expect that this habitat zone will have to be wider than if it were in more natural condition in order to provide the values of buffer zones discussed above. Also, because the values and functions of these zones are diverse, we prefer the term **auxiliary habitat** to buffer zone in this case. Our working hypothesis is that this zone should be at least one mile wide around the Grasslands Management Area to provide these values and functions. Specifically:

1. Any additional development, especially urban, should be prohibited in the one-mile wide (or more) auxiliary habitat zone unless detailed ecological research demonstrates that the development will not compromise the habitat values.

2. As a general rule, any activity that fragments habitat or compromises existing connectivity should be prohibited or rigorously mitigated if the wildlife and ecological values of the Grassland Management Area are to be maintained.

3. In particular, the tenuous habitat linkage between the north and south units should not be further fragmented. Rather, restoration and other activities that enhance the linkage should be undertaken as feasible.

4. The auxiliary habitat zone around the Grasslands Management Area should be used to develop, test, and demonstrate agricultural practices that are compatible with wildlife and biodiversity values. Conservation easements or other agreements that foster agricultural practices conducive to native wildlife should be established. For example, selected fields can be left fallow.

5. Some of the agricultural land--especially in areas where wetland/riparian corridors are presently narrower than optimal--should be restored to wetland condition. Further research is needed to determine the location of priority restoration sites and the types of restoration practices needed.

Detailed studies of species of concern in the Grasslands Management Area are also needed to establish with greater certainty the auxiliary habitat width and levels of connectivity required, and the specific types of land use in these zones that are compatible with native wildlife. Critical information includes data on home range size, movements, and habitat preferences. Species of concern are listed in Table 2.

Bibliography

Adams, L.W., and L.E. Dove. 1989. Wildlife reserves and corridors in the urban environment: A guide to ecological landscape planning and resource conservation. National Institute for Urban Wildlife, Columbia, Maryland 1989: i-iv, 1-91.

Azous, Amanda. 1991. An Analysis of Urbanization Effects on Wetland Biological Communities. The Puget Sound Wetlands and Stormwater Research Program. 130 p.

Balogh, J.C. and W.J. Walker. 1992. Golf course management & construction: environmental issues. Lewis Publishers, Boca Raton, Florida.

Barnum, D.A., and N.H. Evliss, Jr. 1991. Impacts of changing irrigation practices of waterfowl habitat use in the southern San Joaquin Valley, California. California Fish and Game 77(1): 10-21.

Batzer, D.P., and V.H. Resh. 1992. Wetland management strategies that enhance waterfowl habitats can also control mosquitoes. Journal of the American Mosquito Control Association 8(2): 117-125.

Best, L.B., D.F. Stauffer, and A.R. Geier. 1978. Evaluating the effects of habitat alteration on birds and small mammals occupying riparian communities. Presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Pine Mountain, Georgia.

Binford, M.W., and M.J. Buchenau. 1993. Riparian greenways and water resources. Pages 69-104 in D.S. Smith and P.C. Hellmund, eds. Ecology of Greeways. University of Minnesota Press, Minneapolis, MN.

Bingham, S.C., P.W. Westerman, M.R. Overcash. 1980. Effects of grass buffer zone length in reducing the pollution from land application areas. Transactions of the American Society of Agricultural Engineers (ASAE) 23: 330-342.

Bridges, C. 1989. Waterfowl Habitat Management of Public Lands: a Strategy for the Future. Department of the Interior, Bureau of Land Management Publication.

Brittingham, M.C., and S.A. Temple. 1983. Have cowbirds caused forest songbirds to decline? BioScience 33: 31-35.

Brode, John M. and R. Bruce Bury. 1981. The Importance of Riparian Systems To Amphibians and Reptiles. p. 30-36. In: Proc. California Riparian Systems Conference. Univ. Calif, Davis. Davis, Calif.

Brown, M.T. and J.A. Lynch. 1987. Buffer Zones for Water, Wetland, and Wildlife. A Final Report on the Evaluation of the Applicability of Upland Buffers for the Wetlands of the Wekiva Basin. Prepared for the St. Johns River Water Management District by the Center for Wetlands, University of Florida, Gainesville, Florida 32611. 163pp.

Brown, M.T., J.M. Schaefer, K.H. Brandt, S.J. Doherty, C.D. Dove, J.P. Dudley, D.A. Eifler, L.D. Harris, R.F. Noss, and R.W. Wolfe. 1987. An Evaluation of the Applicability of Upland Buffers for the Wetlands of the Wekiva Basin. Center for Wetlands, University of Florida, Gainesville, FL.

Burgess, R.L., and D.M. Sharpe, eds. 1981. Forest Island Dynamics in Man-Dominated Landscapes. Springer-Verlag, New York.

Burns, J.W. 1978. Planning for riparian vegetation management on the Sacramento River, California. pp. 178-183. In Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. USDA Forest Service General Technical Report WD-12.

Castelle, A.J., C. Connoly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S. Mauermann, T. Erickson, and S.S. Cooke. 1992. Wetland Buffers: Use and Effectiveness. Adolfson Associates, Inc. Shorelands and Coastal Zone Management Program, Washington Department of Ecology. Publ. No. 92-10. Olympia, WA.

Childress, D., T. Rothe. 1990. Management of Pacific Flyway geese: an exercise in complexity and frustration.

Transactions of the North American Wildlife and Natural Resources Conference 54: .327-332.

Cooke, S. and C. Conolly. 1990. Effects of Urban Stomwater Runoff on Palustrine Wetland Vegetation, 1989 investigation. U.S. Environmental Protection Agency, Region 10 (in process).

Cook, S.S. 1992. Wetland buffers: A field evaluation of buffer effectiveness in Puget Sound. Pages 61-133 in A.J. Castelle, C. Connoly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S. Mauermann, T. Erickson, and S.S. Cooke. Wetland Buffers: Use and Effectiveness.

Adolfson Associates, Inc. Shorelands and Coastal Zone Management Program, Washington Department of Ecology. Publ. No. 92-10. Olympia, WA.

Cohen, S.Z., T.E. Durborow, and N.L. Barnes. 1993. Growndwater and surface water risk assessments for proposed golf courses. ACS Symposium Ser. Am. Chem. Soc. 522: 214-227.

Corbett, E.S. and J.A. Lynch. 1985. Management of streamside zones on municipal watersheds. pp. 187-190. In R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Folliott, and R.H. Hamre (eds), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. USDA Forest Service General Technical Report RM-120.

Dahl, T.D. 1990. Wetland losses in the United States, 1780s to 1980s. USDI Fish and Wildlife Service, Wasdhington, DC.

Diamond, J.M. 1975. The island dilemma: Lessons of modern biogeographic studies for the design of natural preserves. Biological Conservation 7: 129-146.

Dobkin, D.S. and B.A. Wilcox. 1986 Analysis of natural forest fragments: riparian birds in the Toiyabe Mountains, Nevada. In Verner, J., Morrison, M.L. and Ralph, C.J. [Eds]. Wildlife 2000: modelling habitat relationships of terrestrial vertebrates. Universtiy of Wisconsin Press, Madison.

Ehrenfeld, J.G. 1983. The effects of changes in land-use on swamps of the New Jersey Pine Barrens. Biological Conservation 25: 353-375.

Eng, L.L. 1984. Rare, threatened and endangered invertebrates in California riparian systems, p. 915-919. In Warner, R.E. and K.M. Hendrix [eds]. California Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley and Los Angeles, California.

Exum, J.H. and B.W. Breedlove. 1985. Optimization of wetland habitat value in a rapidly urbanizing watershed. pp. 38-43. In: Proceedings of the National Wetland Symposium: Urban Wetlands. US Fish and Wildlife Serv., U.S. EPA, and, U.S. Army Corp Engineers, Oakland, CA.

Fog, J. 1980. Methods and results of wetland management for waterfowl. Acta Ornithologica 17(12):147-160.

Frazer, S.E. and G.W. Kramer. 1984. Assisting private landowners with wetland habitat developments in California. Calif.-Neva. Wildl. p.33-38.

Frederickson, L.H. and M. Laubhan. 1994. Land use impacts and habitat preservation in the grasslands of western Merced County, California. Report to the Grassland Water District.

Graber, D.A., Kirby, R.E. & Taylor, T.S. [eds]. 1988 North American wood duck symposium: selected papers from the symposium held in St. Louis, Missouri, 20-22 February 1988.

Johnson, A.W., and D.M. Ryba. 1992. A literature review of recommended buffer widths to maintain various functions of stream riparian areas. Prepared for King County Surface Water Management Division, Seattle, WA. 31 pp.

Johnston, C.A. 1994. Cumulative impacts to wetlands. Wetlands 14(1): 49-55.

Kadlec, J.A. and L.M. Smith. 1992. Habitat management for breeding areas, p. 590-610. In Batt [ed]. Ecology and management of breeding waterfowl. University of Minnesota Press.

Kareiva, P. 1987. Habitat fragmentation and the the stability of predator-prey interactions. Nature 326: 388-390.

Katibah, E.F. 1984. A brief history of riparian forests in the Central Valley of California, p. 23-29. In Warner, R.E. and K.M. Hendrix [eds]. California Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley and Los Angeles, California.

Kauffman, J.B. 1988. The status of riparian habitats in Pacific Northwest forests. In Streamside Management: Riparian Wildlife and Forestry Interactions. University of Washington, Seattle, WA.

Keller, C.M.E., C.S. Robbins, and J.S. Hatfield. 1993 Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands 13(2): 137-144.

Kirsch, L.M. 1969. Waterfowl production in relation to grazing. J. Wildl. Manage. 33:821-828.

Kozlik, F.M. 1963. Waterfowl of California. State of California Department of Fish and Game, Sacramento.

Kushlan, J.A. 1979. Design and management of continental wildlife reserves: Lessons from the Everglades. Biological Conservation 15: 281-290.

Laudenslayer, W.F. 1986. Summary: predicting effects of habitat patchiness and fragmentation-the manager's viewpoint, p. 325-327. Verner, J., Morrison, M.L. and Ralph, C.J. [eds]. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Universtiy of Wisconsin Press, Madison.

Lee, C.R. 1985. Minimizing adverse impacts on wetlands of water quality associated with forest and agricultural practices. Proceeding of the conference--wetlands of the Chesapeake / H.A. Groman et al [eds].

Long, R.H.B., S.M. Benson, T.K. Tokunaga, and A. Yee. 1990. Selenium immobilization in a pond sediment at Kesterson Reservoir. Journal of Environmental Quality 19: 302-311.

Lowrance, R., R. Leonard, and J. Sheridan. 1985. Managing riparian ecosystems to control nonpoint pollution. Journal of Soil and Water Conservation Jan./Feb.: 87-91.

Loyn, R.H. 1987. Effects of patch area and habitat on bird abundances, species numbers and tree health in fragmented Victorian forests. pp. 65-75. In Saunders, D.A., Arnold, G.W., Burbridge, A.A., and Hopkins, A.J.M. [eds]. Nature conservation: the role of remnants of native vegetation. Surrey Beatty & Sons Pty Limited, Austrilia.

Lynch, J.A., E.S. Corbett, and K. Mussallem. 1985. Best management practices for controlling nonpoint-source pollution of forested watersheds. J. Soil and Water Conservation 40:164-167.

Lynch, J.F. 1987. Responses of breeding bird communities to forest fragmentation. Pages 123-140 in D.A. Saunders, G.W. Arnold, A.A. Burbidge, and A.J.M. Hopkins, eds. Nature Conservation: The Role of Remnants of Native Vegetation. Surrey Beatty and Sons, Chipping Norton, NSW, Australia.

MacArthur, R.H., and E.O. Wilson. 1963. An equilibrium theory of insular zoogeography. Evolution 17: 373-387.

MacArthur, R.H., and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, NJ.

Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29: 81-96.

Mader, H.J., C. Schell, and P. Kornacker. 1990. Linear barriers to movements in the landscape. Biological Conservation 54: 209-222.

Martinson, R.K. 1978. Waterfowl regulation standardization, Pacific Flyway and High Plains management unit. International Waterfowl Symposium 3 1978. 115-118.

Mathias, M.S., and P. Moyle. 1992. Wetland and aquatic habitats. Agric. Ecosyst. Environ. Amsterdam 42: 165-176.

Mellano, V.J. 1993. The urban connection: farm advisor's role take on new direction. Calif. Grow 17: 39-40.

Merriam, G. 1988. Landscape dynamics in farmland. Trends in Ecology and Evolution 3: 16-20.

Merriam, G. 1991. Corridors and connectivity: Animal populations in heterogeneous environments. Pages 133-142 in D.A. Saunders and R.J. Hobbs, eds. Nature Conservation 2: The Role of Corridors. Surrey Beatty and Sons, Chipping Norton, NSW, Australia.

Merriam, G. and J. Wegner. 1992. Local extinctions, habitat fragmentation, and ecotones. Ecol. Stud. Anal. Synth. 92: 150-169.

Meyers, J.P. 1985. Wildlife and urban wetlands. pp. 28-30. In Proceedings of the National Wetland Symposium: Urban Wetlands. U.S. Fish and Wildlife Serv., U.S. EPA, and, U.S. Army Corp Engineers.

Milligan, D.A. 1985. The ecology of avian use of urban freshwater wetlands in King County, Washington. M.S. thesis, University of Washington, Seattle, WA.

Molini, W.A. 1989. Pacific flyway perspectives and expectations. Transactions of the North American Wildlife and Natural Resources Conference 54: 529-536.

Naiman, R.J., H. Decamps, J. Pastor, and C.A. Johnston. 1988. The Potential Importance of Boundaries to Fluvial Ecosystems. Journal of the North American Benthological Society 7: 289-306.

Nelson, J. 1989. Agriculture, wetlands, and endangered species: The Food Security Act of 1985. Endangered Species Technical Bulletin 14(5): 1, 6-8.

Newbold, J.D., D.C. Erman, and K.B. Roby. 1980. Effect of logging on macroinvertebrates in streams with and without buffer strips. Can.J. Fish. Aquat. Sci. 37:1076-1085.

Nokes, G.D., and E.S. Smith. 1989 San Joaquin Valley evaporation basins-a threat to wildlife. Toxic substances in agricultural water supply and drainage: defining the problems: proceedings from the 1986 regional meetings sponsored by the U.S. Comm. on Irrig and Drainage.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. BioScience 33: 700-706.

Noss, R.F. 1987. Protecting natural areas in fragmented landscapes. Natural Areas Journal 7: 2-13.

Noss, R.F. 1987b. Corridors in real landscapes: A reply to Simberloff and Cox. Conservation Biology 1: 159-164.

Noss, R.F. 1992. The Wildlands Project: Land conservation strategy. Wild Earth (Special Issue): 10-25.

Noss, R.F. 1993. Wildlife corridors. Pages 43-68 in D.S. Smith and P.C. Hellmund, eds. Ecology of Greeways. University of Minnesota Press, Minneapolis, MN.

Noss, R.F., and A. Cooperrider. 1994. Saving Nature's Legacy: Protecting and Restoring Biodiversity. Defenders of Wildlife and Island Press, Washington, DC.

Noss, R.F., and B. Csuti. 1994. Habitat fragmentation. Pages 237-264 in G.K. Meffe and R.C. Carroll, eds. Principles of Conservation Biology. Sinauer Associates, Sunderland, MA.

Noss, R.F., and L.D. Harris. 1986. Nodes, networks, and MUMs: Preserving diversity at all scales. Environmental Management 10: 299-309.

Opdam, P. 1991. Metapopulation theory and habitat fragmentation: a review of holarctic breeding bird studies. Landscape Ecology 5: 93-106.

Overcash, M.R., S.C. Bingham, and P.W. Westerman. 1981. Predicting Runoff Pollutant Reduction in Buffer Zones Adjacent to Land Treatment Sites. Transactions of the American Society of Agricultural Engineers (ASAE), pp. 430-435.

Oxley, D.J., M.B. Fenton, and G.R. Carmody. 1974. The effects of roads on populations of small mammals. Journal of Applied Ecology 11: 51-59.

Perrochet, P., A. Musy. 1992. A simple formula to calculate the width of hydrological buffer zones between drained agricultural plots and nature preserve areas. Irrigation and Drainage Systems 6: 69-81.

Quinn, J.F. and S.P. Harrison. 1988. Effect of habitat fragmentation and isolation on species richness: evidence from biogeographic patterns. Oecologia (Berlin) 75: 132-140.

Rolstad, J. 1991. Consequences of forest fragmentation for the dynamics of bird populations: conceptual issues and the evidence. Biological Journal of the Linnean Society 42: 149-163.

Roman, C.T., and R.E. Good. 1985 Delineating wetland buffer protection areas: the New Jersey Pinelands model. pp. 224-230. In Proceedings of the National Wetland Symposium: Urban Wetlands. U.S. Fish and Wildlife Serv., U.S. EPA, and U.S. Army Corp Engineers.

Salwasser, H., and K. Shimamoto 1984. Pronghor, cattle and feral horse use of wetland and upland habitats. Californian Riparian Systems: Ecology, Conservation, and Productive Management R.E. Warner and K.M. Hendrix [eds]. University of California, Berkeley and Los Angeles, California.

Sands, A. 1978. Public involvement in riparian habitat protection; a California case history. pp. 216-227. In Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. USDA Forest Service General Technical Report WD-12.

Schaefer, J.M., and M.T. Brown. 1992. Designing and protecting river corridors for wildlife. Rivers 3: 14-26.

Schlorff, R.W., and P.H. Bloom. 1984. Importance of riparian systems to nesting Swainson's hawks in the Central Valley of California, p. 612-618. In Warner, R.E. and K.M. Hendrix [eds]. California Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley and Los Angeles, California.

Schlosser, I.J. and J.R. Karr. 1981. Water quality in agricultural watersheds: impact of riparian vegetation during base flow. Water Resources Bulletin 17: 233-240.

Schmidly, D.J. and R.B. Ditton. 1978. Relating human activities and biological resources in riparian habitats of western Texas. pp. 107-116. In Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. USDA Forest Service General Technical Report WD-12.

Schroeder, R.L., and A.W. Allen. 1992. Assessment of habitat of wildlife communities on the Snake River, Jackson, Wyoming. USDI Fish and Wildlife Service, Resource Publication 190.

Simberloff, D. and J. Cox. 1987. Consequences and costs of conservation corridors. Conservation Biology 1: 63-71.

Simberloff, D., J.A. Farr, J. Cox, and D.W. Mehlman. 1992. Movement corridors: Conservation bargains or poor investments? Conservation Biology 6: 493-504.

Smith, L.M., J.A. Kadlec, and P.V. Fonnesbeck. 1984. Effects of prescribed burning on nutritive quality of marsh plants in Utah. Journal of Wildlife Management 48: 285-288.

Smith, L.M., R.L. Pederson, and R.M. Kaminski. 1989. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, Texas.

Sousa, P.J. and A.H. Farmer. 1983. Habitat suitability index models: wood duck. U.S. Fish and Wildlife Service, FWS/OBS-82/10.43.

Stanley, S.M. 1990. The general correlation between rate of speciation and rate of extinction: fortuitous causal linkages. Ross, R.M. and W.D. Allmon [eds]. Causes of evolution: a paleontological perspective. University of Chicago Press, Chicago and London.

Swihart, R.K., and N.A. Slade. 1984. Road crossing in Sigmodon hispidus and Microtus ochrogaster. Journal of Mammalogy 65: 357-360.

Tanner, C.C. 1992. A review of cattle grazing effects on lake margin vegetation with observations from Dune Lakes in Northland, New Zealand. New Zealand Natural Sciences 19: 1-14.

Taylor, B. 1991 Investigating species incidence over habitat fragments of different areas-a look at error estimation. Biological Journal of the Linnean Society 42: 177-191.

Temple, S.A. 1991. The role of dispersal in the maintenance of bird populations in a fragmented landscape pp. 2298-2305. Bell, B.D., R.O. Cossee, J.E.C. Flux, B.D. Heather, R.A. Hitchmough, C.J.R. Robertson, and M.J. Williams [Eds]. Acta 20 Congressus Internationalis Ornithologici. December 1990.

Templeton, A.R., K. Shaw, E. Routman, and S.K. Davis. 1990. The genetic consequences of habitat fragmentation. Ann. Mo. Bot. Gard 77:13-27.

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. A Conservation Strategy for the Northern Spotted Owl. USDA Forest Service, USDI Bureau of Land Management, USDI Fish and Wildlife Service, and USDI National Park Service, Portland, OR.

UNESCO. 1974. Task Force on Criteria and Guidelines for the Choice and Establishment of Biosphere Reserves. Man and the Biosphere Report No. 22. Paris, France.

Usher, M.B. 1987. Effects of fragmentation on communities and populations: a review with applications to wildlife conservation, pp. 103-121. In D.A. Saunders, G.W. Arnold, A.A. Burbridge, and A.J.M. Hopkins [eds]. Nature conservation: the role of remnants of native vegetation. Surrey Beatty and Sons Pty Limited, Australia.

van Apeldoorn, R.C. 1989. Small mammals in patchy landscapes: a review. Lutra 32: 21-41.

Weller, M.W., G.W. Kaufmann, and P.A. Vohs, Jr. 1991. Evaluation of wetland develpment and waterbird response at Elk Creek wildlife management area, Lake Mills, Iowa, 1961 to 1990. Wetlands 11: 245-262.

Weller, M.W. 1990. Waterfowl management techniques for wetland enhancement, restoration and creation useful in mitigation procedures, p. 517-528. In J.A. Kusler and M.E. Kentula, Wetland Creation and Restoration. Island Press, Washington, D.C.

Whitcomb, R.F., C.S. Robbins, J.F. Lynch, B.L. Whitcomb, K. Klimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pages 125-205 in R.L. Burgess and D.M. Sharpe, eds. Forest Island Dynamics in Man-dominated Landscapes. Springer-Verlag, New York.

White, M.R., R.D. Pieper, G.B. Donart, and L.W. Triafo. 1991. Vegetational response to short-duration and continuous grazing in southcentral New Mexico. Journal of Range Management 44: 399-403.

Wiens, J.A. 1989. The Ecology of Bird Communities. Vol. 2. Processes and Variations. Cambridge University Press, New York.

Wilcove, D.S., M. McMillan, and K.C. Winston. 1993. What exactly is an endangered species? An analysis of the U.S. Endangered Species list: 1985-1991. Conservation Biology 7: 87-93.

Wilcox, B.A., and D.D. Murphy. 1985. Conservation strategy: The effects of fragmentation on extinction. American Naturalist 125: 879-887.

Williams J.D. and C.K. Dodd, Jr. 1978. Importance of Wetlands to Endangered and Threatened Species. pp. 565-575. In: Phillip E. Greeson, John R. Clark, and Judith E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. American Water Resources Association.

Witmer, G.W. 1985. Assessing cumulative impacts to wetlands, pp. 204-208. In: Proceedings of the National Wetland Symposium: Urban Wetlands. U.S. Fish and Wildlife Serv., U.S. EPA, and, U.S. Army Corp Engineers.

Wohlgemuth, S. 1991. Ballona wetlands. A success story! Western Tanager 57: 1-4.

Wong, S.L. and R.H. McCuen. 1982. The Design of Vegetative Buffer Strips For Runoff and Sediment Control. A Technical Paper Developed as Part of a Study of Stormwater Management in Coastal Areas Funded by Maryland Coastal Zone Management Program. 23 p.

Yong, R.A., T. Huntrods, and W. Anderson. 1980. Effectiveness of Vegetated Buffer Strips in Controlling Pollution from Feedlot Runoff. J Environ. Qual. 9: 483-497.

Zedler, J.B. 1983. Freshwater Impacts in Normally Hypersaline Marshes. Estuaries 6: 346-355.

Table 1. Determinants of functional connectivity (from Noss and Cooperrider 1994).

1. Mobility or dispersal characteristics of the target species

    a. species-specific habitat preferences for movement

    b. dispersal distance or scale of resource utilization

    c. rate of movement or dispersal (through various types of habitats)

2. Other autecological characteristics of the target species (e.g., preference for particular plant species or structural features of the habitat; feeding and nesting requirements; mortality risks)

3. Landscape context: Structural characteristics and spatial pattern of landscape (patch, corridors, matrix, mosaics)

4. Distance between patches of suitable habitat

5. Presence of barriers to movement (e.g., rivers, roads)

6. Interference from humans, predators, etc.

Table 2. Species of concern in the Grasslands study area.

A joint Federal/State/local government task force has been established to focus on Kern County (San Joaquin Valley), California, endangered species issues. The primary objective of the task force is to develop a plan to conserve listed and candidate species and their habitats. The planning area encompasses the known range of the blunt nosed leopard lizard (*Gambelia silus*), San Joaquin kit fox (*Vulpes macrotis mutica*) and giant kangaroo rat (*Dipodomys ingens*).

[cited in *Endangered Species, Technical Bulletin* vol. XIII(6-7): 3]

Listed species

Blunt-nosed leopard lizard, *Gambelia silus* (E) [habitat mitigation, *Endangered Species, Technical Bulletin*, May, 1987; habitat conservation under Farm bill, *Endangered Species, Technical Bulletin,* May, 1989.]

American peregrine falcon, *Falco peregrinus analus* (E)

San Joaquin kit fox, *Vulpes macrotis mutica* (E) [habitat mitigation, *Endangered Species, Technical Bulletin*, May, 1987.]

Fresno kangaroo rat, *Dipodomys nitratoides exilis* (E) [no references]

Giant kangaroo rat, *D. ingens* (E) [oil exploration concern, *Endangered Species, Technical Bulletin*, Sep. 1987]

Tipton kangaroo rat, *D. nitratoides nitratoides* (E) [approved listing, *Endangered Species, Technical Bulletin*, Aug. 1988]

Valley elderberry longhorn beetle, *Desmocerus californicus dimorphus* (T) [mitigation of habitat loss, *Endangered Species, Technical Bulletin*, Mar, 1986]

Hoovers wooly-star, *Eriastrum hooveri* (T) [notes on threats to habitat, *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

Giant garter snake, *Thamnophis gigas* (E)

Vernal pool fairy shrimp, *Branchinecta lynchi* (E)

Califonia linderiella, *Linderiella occidentalis* (E)

Candidate Species

California tiger salamander, *Ambystoma californiense* [no references]

Western spadefoot toad, *Scaphiopus hammondi hammondi* [no references]

Tricolored blackbird, *Agelaius tricolor* [no references]

White-faced ibis, *Plegadis chihi* [no references]

Mountain plover, *Charadrius montanus* [no references]

California horned lark, *Eremophila alpestris actia* [no references]

Loggerhead shrike, *Lanius ludovicianus* [no references]

Western snowy plover, interior population, *Charadrius alexandrinus nivosus* [no references]

Pacific western big-eared bat, *Plecotus townsendii townsendii* [no references]

Riparian brush rabbit, *Sylvilagus bachmani riparius* [no references]

San Joaquin Valley woodrat, *Veotoma fuscipes riparia* [no references]

San Joaquin dune beetle, *Coelus gracilis* [no references]

Ciervo aegialian scarab beetle, *Aegialia concinna* [no references]

Heartscale, *Atriplex cordulata* [notes on distibution *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

Valley spearscale, *A. joaquiniana* [notes on distibution and threats *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

Fleshy owl's clover, *Castilleja camperstris* [notes on distribution and threats *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

Hispid bird's beak, *Cordylanthus molls* ssp. *hispidus* [notes on distribution and threats *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

Delta coyote thistle, *Eryngium racemosum* [notes on distribution and threats *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

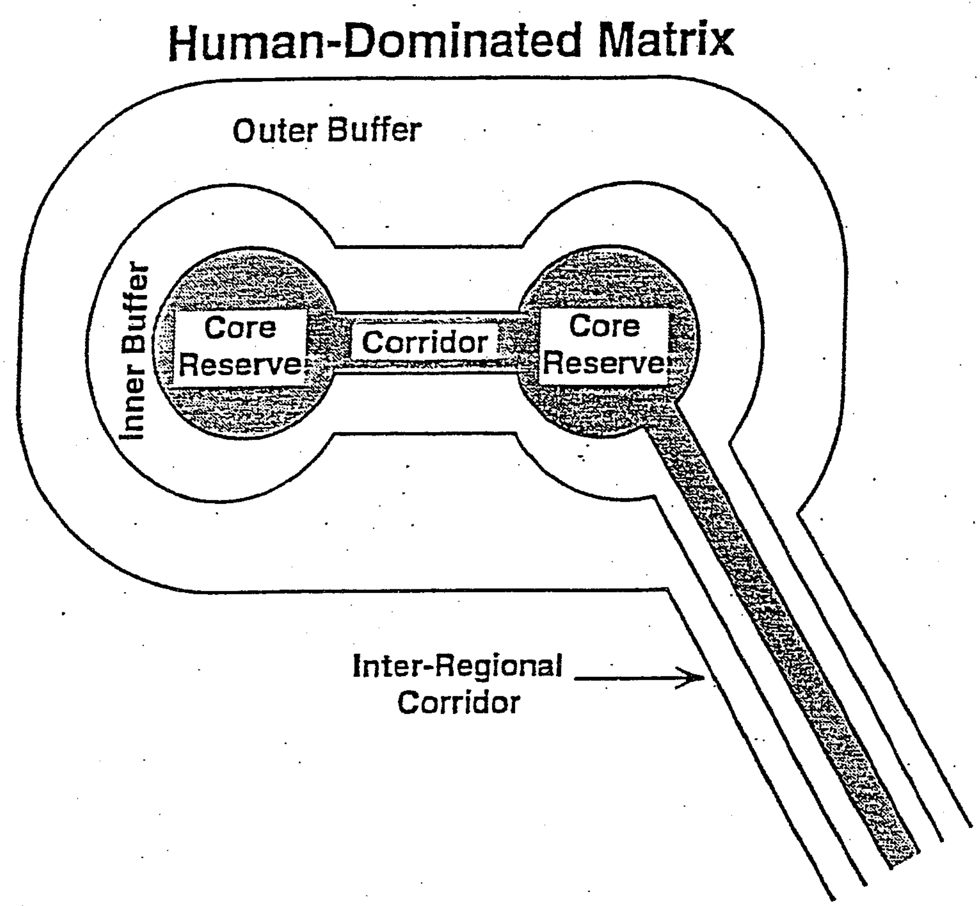
Merced monardella, *Monardella leucocephala* [notes on distribution and threats *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

Colusa grass, *Neostapfia colusana* [notes on distribution and threats *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

San Joaquin orcutt grass, *Orcuttia inaequalis* [notes on distribution and threats *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

Arburua Ranch jewelflower, *Streptanthus insignis* ssp. *lyonii* [notes on distribution and threats *California Native Plant Society's Inventory of Rare and Endangered Vascular Plants of California*]

Fig. 1. A model reserve network for a human-dominated region, consisting of core reserves, connecting corridors or linkages, and multiple-use buffer zones. Only two core reserves are shown, but a real system may contain many reserves. Outer buffer zones would allow a wider range of compatible human activities than inner buffer zones. In this example, an interregional corridor connects the system to a similar network in another natural region. Adapted from Noss (1992).



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APPENDIX B.

Extensive mapping of geographic information was used to support the recommendations of this study. The digital database, about 325 megabytes of data, includes maps and tabular data all georeferenced and essentially linked to each other. Map based data was translated, and converted as necessary for imput into UNIX based ARC/INFO. Tabular data were input into INFO or left in dos-based spreadsheets with each data item cross referenced to some ARC/INFO attribute (for example MAP INDEX in the Natural Diversity Database and PARCEL # in the Pesticide Permit Application from the Agricultural Commission)

Below is a list of the coverages most used in the study, a listing of the contents of the the computer directories, and the code for each of the AML (ARC Macro Language) scripts used to generate the presentation maps. They are available in the /home/lgwd directory.

All coverages are in the UTM projection, datum NAD27, meters. This allows them to be overlaid on the erdas image file (t4334gras.gis). The source of the data is in parenthesis. Items with an * have detailed code and annotation information in the Data Dictionary folder (ddf).

Coverages preceeded with a # are also to be found as export files *.e00 files in /home/lgwd/arcview. These can be "ftp-ed" (File Transfer Protocol) over to dos for viewing and printing on Arcview.

ANNEX -potential annexations from the 1994 Los Banos General Plan. (TRA)
AINTEREST -expanded sphere of influence identified in 1994 Los Banos General Plan (TRA)
AIMPACT -an area identified for planning purposes in the 1994 Los Banos Beneral Plan, larger than AINTEREST, that includes the area that should be considered when implementing the general plan.
AROADS -all roads within the study area, the .aat has all street names that can be used in arcplot for labeling purposes or in arcedit (item = stname) to id.(MDSS)
BOOK428 * -parcels in Book428 refer to assessor book code, see below (MDSS)
CENSUS90 * -tiger census data for annotation code see data dictionary (TEALE/MDSS)
CORRCLIP - clip coverage to focus on the corridor area (TRA)
COUNTY-the county bnd (MDSS)
FLYLOC -flyover locations for pintail data, karen has joe's write-up about the data (NBB/JOE FLESCKES/TRA)
GENPLAN -outer boundary of general plans for all cities in Merced county(MDSS)
GGP -Gustine general plan with zoning info (MDSS)
GWD -Grassland Water District Boundary (MDSS)
GRIDPOPSP -Projected population coverage- not trnsferred into utm (MDSS)
WDONE -One mile buffer around GWD (TRA)
GWMA -Grassland Wildlife Management Area (MDSS)
GWMAONE- One mile buffer around GWMA (TRA)
GWMASA -Study Area = 2 mile buffer around Grassland Wildlife Manag (MDSS)
LBGP -Los Banos general plan with zoning info (MDSS)
LU90 -1990 Landuse (MDSS/DEPT OF CONSERVATION)
MROAD -main roads in the GWMA study area see aroads(MDSS)

MUNI -municipal boundaries for cities within Merced Co.(MDSS)
NDDB * -Natural Diversity Database point and polygon coverage for all CA rare, threatened and Endangered species. The associated file, nddbdata.df, an upload of the current RareFind database, is accessible only through tables. It is VERY important not to build or clean this coverage! More details are in ddf (CAF&G/NATURAL HERITAGE DIVISION)
NDDBLGWD -NDDB clipped to the corridor area. Unlike the CA wide NDDB this coverage has all the RareFind data directly associated with the arc coverage making it accessible to arcedit, arcplot and arcview. (CAF&G/NATURAL HERITAGE DIVISION/TRA)

The following coverages contain parcel data. Each is numbered with the county assessor book reference code. A map showing the locations of each these book numbers is in the ddf. The assessor's code includes contract (4242) and noncontract (4343) duck clubs, however this information is only available through the INFO datafile PINFO for all but the corridor focus area. The corridor focus area (PARCORR) has all associated code information embedded into it directly.

PARCORR - parcels in the corridor focus area, information from the INFO file PINFO, which can be accessed through TABLES, is already embedded in this coverage further work should include eliminating unneccesary code item in the pat (TRA/MDSS)
PAR20 (MDSS)
PAR25 (MDSS)
PAR26 (MDSS)
PAR40 (MDSS)
PAR45 (MDSS)
PAR49 (MDSS)
PAR54 (MDSS)
PAR55 (MDSS)
PAR56 (MDSS)
PAR59 (MDSS)
PAR63 (MDSS)
PAR64SP - a coverage that refused to be transformed to utm (MDSS)
PAR65 (MDSS)
PAR66 (MDSS)
PAR70 (MDSS)
PAR73 (MDSS)
PAR74 (MDSS)
PAR75 (MDSS)
PAR78 (MDSS)
PAR81 (MDSS)
PAR82 (MDSS)
PAR83 (MDSS)
PAR84 (MDSS)
PAR85 (MDSS)
PAR86 (MDSS)
PAR88 (MDSS)
PAR89 (MDSS)
PAR90 (MDSS)
PARCELSSP - Not transferred to utm, it is an appended file that shows all the arcs in all parcel coverages but has no associated information. (MDSS)

RESE -Reservoirs on the east side of the county(MDSS)
RESW -Reservoirs on the west side of the county(MDSS)
RIVERS - and creeks for the whole county, INFO file include names (item = HLNAME) (MDSS)
SEWERS -shows the sewage ponds for each of the municipalities (MDSS)
SPHERES -sphere of influence for each city (MDSS)
T4334GRAS -an arc/info coverage of the thematic mapper data classified to identify waterfowl habitat. We do not have a good remap table for it yet. The remap table (classlst.rmp) we were sent is not in a readily readable arc/info format. (DU)
T4334GRAS.GIS - an erdas image that shows the 7 waterfowl habitat types in false color and other landuse in straight red/blue/green TM bands. To use it as a base map give the command >image t4334gras.gis (DU)
TOPO15 - outlines of USGS 15' quads for the county (MDSS)
TOPO75 -outline of USGS 7.5' quads for the county(MDSS)
WETLAND - the 1977 National Wetland Inventory data. we have updated 1983 data from DU in /home/lgwd/temp/lisy listed by quad name. They did not send us annotation data, when Barbara comes back from Alaska she will correct this.(MDSS)
WETPOINTS - annotation data for each of the above wetland polygons. (MDSS)

The computer directory listings are also documented in the Data Dictionary.

```
/home/lgwd/tape2
gis1% ls -l
total 152
drwxr-xr-x   2 lgwd    staff      512 Nov  8 03:38 1.map
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:30 annex
drwxr-xr-x   2 lgwd    staff     1024 Nov  7 19:33 aroads
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:30 book428
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:31 census90
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:31 genplan
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:31 ggp
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:32 glanduse
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:32 gridpopsp
drwxr-xr-x   2 lgwd    staff     7680 Nov  8 02:52 info
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:32 lbdiff
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:33 lbgp94
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:33 line
-rw-r--r--   1 lgwd    staff     5993 Nov  8 03:39 log
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:33 lu90
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:32 ludwr
drwxr-xr-x   2 lgwd    staff      512 Nov  8 02:50 ludwrcs
drwxr-xr-x   2 lgwd    staff      512 Nov  8 02:50 ludwrdp
drwxr-xr-x   2 lgwd    staff      512 Nov  8 02:51 ludwrdr
drwxr-xr-x   2 lgwd    staff      512 Nov  8 02:51 ludwri
drwxr-xr-x   2 lgwd    staff      512 Nov  8 02:47 ludwrlb
drwxr-xr-x   2 lgwd    staff      512 Nov  8 02:48 ludwrsl
drwxr-xr-x   2 lgwd    staff      512 Nov  8 02:52 ludwrv
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:33 lulb
drwxr-xr-x   2 lgwd    staff     1024 Nov  7 19:33 mroads2
drwxr-xr-x   2 lgwd    staff      512 Nov  7 19:33 nopclip
```

```
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par20
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par25
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par26
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par40
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par45
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par49
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par54
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par55
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par56
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:33 par59
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par59sp
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par63
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par64
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par64sp
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par65
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par66
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par70
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par73
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par74
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par75
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par78
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par81
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par82
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par83
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par84
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par85
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par86
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:34 par88
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:35 par89
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:35 par90
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:35 parcorr
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:35 sewers
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:35 topo15
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:35 topo75
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:36 wetland
drwxr-xr-x  2 lgwd   staff    512 Nov  7 19:36 wetpoints
/home/lgwd
gis1% ls -l
total 214
drwxr-xr-x  2 lgwd   staff    512 Oct 11 16:05 ainterest
drwxr-xr-x  2 lgwd   staff   2048 Nov  7 15:36 amls
drwxr-xr-x  2 lgwd   staff    512 Oct 11 16:05 annex
drwxr-xr-x  2 lgwd   staff    512 Oct 14 17:31 close
drwxr-xr-x  2 lgwd   staff    512 Oct 11 16:05 gwmabndstxt
drwxrwxrwx  2 root   other  16384 Nov  8 02:14 info
-rwxrwxrwx  1 13102  20     61277 Nov  7 23:53 log
drwxr-xr-x  2 lgwd   staff    512 Oct 11 16:05 map1
-rw-r--r--  1 lgwd   staff    519 Oct 24 14:00 newcshrc2
-rw-r--r--  1 lgwd   staff    527 Oct 24 14:00 newcshrc2%
drwxr-xr-x  2 lgwd   staff    512 Oct 11 16:05 nop2.ps
```

```
-rw-r--r--   1 lgwd    staff       287 Aug 30 06:03 offmaps
-rw-r--r--   1 lgwd    staff       264 Aug 30 06:03 offmaps%
-rwxrwxrwx   1 lgwd    staff       373 Jul 15 21:37 oldcshrc1
drwxr-xr-x   2 lgwd    staff       512 Oct 11 16:05 page
drwxr-xr-x  46 lgwd    staff      2048 Nov  8 08:21 show
drwxr-xr-x  63 lgwd    staff      1536 Nov  8 03:39 tape2
drwxr-xr-x   3 lgwd    staff       512 Nov  1 17:00 temp
-rw-r--r--   1 lgwd    staff      2998 Jul 20 15:02 toprint
-rw-r--r--   1 lgwd    staff      2963 Jul 20 15:02 toprint%
drwxr-xr-x   2 lgwd    staff      1536 Nov  8 08:30 txt
drwxr-xr-x   3 lgwd    staff       512 Jul 21 15:38 utm
-rw-r--r--   1 lgwd    staff       936 Aug 12 13:15 wetnames
-rw-r--r--   1 lgwd    staff       124 Aug 12 13:15 wetnamex

/home/lgwd/show
gis1% ls -l
total 45074
drwxr-xr-x   2 lgwd    staff       512 Nov  8 03:43 1.map
-rw-r--r--   1 lgwd    staff  11559894 Nov  8 08:21 1.ps
-rw-r--r--   1 lgwd    staff      2073 Nov  1 17:06 1intro.aml
-rw-r--r--   1 lgwd    staff      7649 Nov  8 01:25 1present.aml
-rw-r--r--   1 lgwd    staff      7654 Nov  8 01:25 1present.aml%
-rw-r--r--   1 lgwd    staff      2578 Nov  8 03:16 2image.aml
-rw-r--r--   1 lgwd    staff      2564 Nov  8 03:16 2image.aml%
-rw-r--r--   1 lgwd    staff      2563 Nov  8 03:21 3close.aml
-rw-r--r--   1 lgwd    staff      2418 Nov  8 03:21 3close.aml%
-rw-r--r--   1 lgwd    staff      1657 Nov  8 00:02 4shorebird.aml
-rw-r--r--   1 lgwd    staff      1641 Nov  8 00:02 4shorebird.aml%
-rw-r--r--   1 lgwd    staff      2088 Nov  8 03:27 5mapfly.aml
-rw-r--r--   1 lgwd    staff      2023 Nov  8 03:27 5mapfly.aml%
-rw-r--r--   1 lgwd    staff      1746 Nov  8 00:07 5prnt.aml
-rw-r--r--   1 lgwd    staff      1747 Nov  8 00:07 5prnt.aml%
drwxr-xr-x   2 lgwd    staff       512 Nov  8 01:49 5prnt.map
-rw-r--r--   1 lgwd    staff   2181770 Nov  8 01:53 5prnt.ps
-rw-r--r--   1 lgwd    staff      1534 Nov  8 03:29 6nddb.aml
-rw-r--r--   1 lgwd    staff      1545 Nov  8 03:29 6nddb.aml%
-rw-r--r--   1 lgwd    staff       574 Nov  8 00:30 6prnt.aml
-rw-r--r--   1 lgwd    staff       574 Nov  8 00:30 6prnt.aml%
drwxr-xr-x   2 lgwd    staff       512 Nov  8 01:49 6prnt.map
-rw-r--r--   1 lgwd    staff    207930 Nov  8 01:54 6prnt.ps
-rw-r--r--   1 lgwd    staff      1926 Nov  1 17:08 7lbgp.aml
-rw-r--r--   1 lgwd    staff       393 Nov  8 00:49 7prnt.aml
-rw-r--r--   1 lgwd    staff       424 Nov  8 00:49 7prnt.aml%
drwxr-xr-x   2 lgwd    staff       512 Nov  8 01:49 7prnt.map
-rw-r--r--   1 lgwd    staff   1539716 Nov  8 01:55 7prnt.ps
-rw-r--r--   1 lgwd    staff      1874 Nov  1 17:08 8biosph.aml
-rw-r--r--   1 lgwd    staff      1057 Nov  8 01:10 8prnt.aml
-rw-r--r--   1 lgwd    staff      1037 Nov  8 01:05 8prnt.aml%
drwxr-xr-x   2 lgwd    staff      1024 Nov  8 01:48 8prnt.map
-rw-r--r--   1 lgwd    staff   2154819 Nov  8 01:59 8prnt.ps
```

```
-rw-r--r--   1 lgwd    staff      1052 Nov  8 01:26 8sph.aml
-rw-r--r--   1 lgwd    staff      1039 Nov  8 01:26 8sph.aml%
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 aimpact
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:24 ainterest
drwxr-xr-x   2 lgwd    staff      2048 Nov  8 01:00 amls
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 canals
drwxr-xr-x   2 lgwd    staff       512 Nov  7 23:59 close.map
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 county
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 flyloc
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 gp94lb
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 gwd
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:27 gwdone
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 gwma
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 gwmabnds
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 gwmabndstxt
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:27 gwmaone
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 gwmasa
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 gwmasph
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 hth
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 hyd100k
drwxr-xr-x   2 lgwd    staff       512 Nov  8 02:00 image.map
-rw-r--r--   1 lgwd    staff   1794898 Nov  8 02:00 image.ps
drwxr-xr-x   2 lgwd    staff      4608 Nov  7 19:24 info
drwxr-xr-x   2 lgwd    staff       512 Nov  8 01:48 intro.map
-rw-r--r--   1 lgwd    staff    224877 Nov  8 01:50 intro.ps
drwxr-xr-x   2 lgwd    staff       512 Nov  8 01:49 lbgp.map
-rw-r--r--   1 lgwd    staff    206810 Nov  8 01:52 lbgp.ps
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 lbgp90
-rw-r--r--   1 lgwd    staff    228579 Nov  1 17:01 lgwd-p01.tif
-rw-r--r--   1 lgwd    staff    197570 Nov  1 17:01 lgwd-p02.tif
-rw-r--r--   1 lgwd    staff    212565 Nov  1 17:01 lgwd-p03.tif
-rw-r--r--   1 lgwd    staff    164399 Nov  1 17:01 lgwd-p04.tif
-rw-r--r--   1 lgwd    staff    254796 Nov  1 17:01 lgwd-p05.tif
-rw-r--r--   1 lgwd    staff    177136 Nov  1 17:01 lgwd-p06.tif
-rw-r--r--   1 lgwd    staff    206385 Nov  1 17:01 lgwd-p07.tif
-rw-r--r--   1 lgwd    staff    222594 Nov  1 17:01 lgwd-p08.tif
-rw-r--r--   1 lgwd    staff    233622 Nov  1 17:01 lgwd-p09.tif
-rw-r--r--   1 lgwd    staff    191703 Nov  1 17:01 lgwd-p10.tif
-rw-r--r--   1 lgwd    staff    189434 Nov  1 17:01 lgwd-p11.tif
-rw-r--r--   1 lgwd    staff      3349 Nov  8 08:21 log
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 lu90corr
drwxr-xr-x   2 lgwd    staff       512 Nov  8 01:49 mapfly.map
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 mrnames
drwxr-xr-x   2 lgwd    staff      1024 Nov  7 19:26 mroads
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 muni90lb
drwxr-xr-x   2 lgwd    staff       512 Nov  8 01:49 nddb.map
-rw-r--r--   1 lgwd    staff    364788 Nov  8 01:51 nddb.ps
drwxr-xr-x   2 lgwd    staff       512 Nov  7 19:26 nddbshow
-rw-r--r--   1 lgwd    staff       431 Nov  8 01:48 prnt.aml
-rw-r--r--   1 lgwd    staff       438 Nov  8 01:48 prnt.aml%
```

```
drwxr-xr-x   2 lgwd   staff      512 Nov  7 19:26 public
drwxr-xr-x   2 lgwd   staff      512 Nov  7 19:26 rese
drwxr-xr-x   2 lgwd   staff      512 Nov  7 19:26 resw
drwxr-xr-x   2 lgwd   staff      512 Nov  7 19:26 rivers
drwxr-xr-x   2 lgwd   staff      512 Nov  7 19:26 roadsgp94
-rw-r--r--   1 lgwd   staff   163066 Nov  8 01:50 shbrd.ps
drwxr-xr-x   2 lgwd   staff      512 Nov  7 19:26 shorebird
drwxr-xr-x   2 lgwd   staff      512 Nov  8 01:48 shorebird.map
drwxr-xr-x   2 lgwd   staff      512 Nov  7 19:26 spheres
drwxr-xr-x   2 lgwd   staff      512 Nov  7 19:26 t4334


gis1% pwd
/home/lgwd/txt
gis1% ls -l
total 1118
-rw-r--r--   1 lgwd   staff      735 Nov  8 09:32 1draw.aml
-rw-r--r--   1 lgwd   staff      732 Nov  8 09:32 1draw.aml%
-rwxrwxrwx   1 lgwd   staff      293 Jul 17 12:07 arcprbl.txt
-rw-r--r--   1 lgwd   staff    28530 Aug 15 11:21 chronlgwd.txt
-rw-r--r--   1 lgwd   staff    37666 Aug 15 11:21 chronlgwd.txt%
-rw-r--r--   1 lgwd   staff      585 Aug 12 13:36 chronmap.txt
-rw-r--r--   1 lgwd   staff      348 Sep  2 13:03 conversions.txt
-rw-r--r--   1 lgwd   staff      307 Sep  2 13:03 conversions.txt%
-rw-r--r--   1 lgwd   staff     5480 Nov  8 08:30 covdoc.dos
-rw-r--r--   1 lgwd   staff     5365 Nov  8 03:32 covdoc.txt
-rw-r--r--   1 lgwd   staff     5374 Nov  8 03:32 covdoc.txt%
-rw-r--r--   1 lgwd   staff      396 Jul 26 00:59 covlst.txt
-rw-r--r--   1 lgwd   staff      396 Jul 26 00:58 covlst.txt%
-rw-r--r--   1 lgwd   staff     5743 Jul 22 18:47 doc.txt
-rw-r--r--   1 lgwd   staff     3086 Jul 26 02:06 hanson.txt
-rwxrwxr-x   1 root   other    26030 Jul 15 12:02 hplaser4.txt
-rw-r--r--   1 lgwd   staff    15587 Aug 16 10:36 hydtext
-rw-r--r--   1 lgwd   staff     3169 Jul 26 02:06 lgwd0723.txt%
-rw-r--r--   1 lgwd   staff     2331 Nov  7 18:21 lgwdnddb.aml
-rw-r--r--   1 lgwd   staff      869 Nov  7 18:29 lgwdnddb2.aml
-rw-r--r--   1 lgwd   staff     2331 Nov  7 18:29 lgwdnddb2.aml%
-rw-r--r--   1 lgwd   staff     3016 Aug 18 19:54 memo0816.txt
-rw-r--r--   1 lgwd   staff     2436 Aug 18 19:54 memo0816.txt%
-rw-r--r--   1 lgwd   staff    16548 Jun 10 11:41 nddb.txt
-rw-r--r--   1 lgwd   staff    10750 Aug 29 12:56 nddbAAT
-rw-r--r--   1 lgwd   staff     2151 Aug 29 13:04 nddbcheck
-rw-r--r--   1 lgwd   staff     3797 Aug 29 13:01 nddbfix
-rw-r--r--   1 lgwd   staff     3827 Aug 29 13:01 nddbfix%
-rw-r--r--   1 lgwd   staff     1929 Aug 29 12:24 nddbfix2
-rw-r--r--   1 lgwd   staff     3827 Aug 29 12:24 nddbfix2%
-rw-r--r--   1 lgwd   staff     2487 Aug 29 12:48 nddbfix3
-rw-r--r--   1 lgwd   staff     2521 Aug 29 12:47 nddbfix3%
-rw-r--r--   1 lgwd   staff    15821 Aug 29 13:03 nddbpat
-rwxrwxrwx   1 lgwd   staff     1103 Jul 17 12:07 problems
```

```
-rwxrwxrwx   1 lgwd     staff      1102 Jul 17 12:07 problems%
-rw-r--r--   1 lgwd     staff       453 Aug 29 10:44 publicpat.aml
-rw-r--r--   1 lgwd     staff      5253 Aug 29 13:52 templgwd.txt
-rw-r--r--   1 lgwd     staff      5252 Aug 29 13:52 templgwd.txt%
-rw-r--r--   1 lgwd     staff      2074 Nov  8 02:40 topmr.txt
-rw-r--r--   1 lgwd     staff     10941 Oct 25 12:13 topnntdir
-rw-r--r--   1 lgwd     staff      8553 Oct 25 12:13 topnntdir%
-rw-r--r--   1 lgwd     staff    140847 Oct 25 11:34 topnntfilelist
-rw-r--r--   1 lgwd     staff     99415 Oct 25 11:34 topnntfilelist%
-rw-r--r--   1 lgwd     staff      1179 Aug 26 16:15 toprint
-rw-r--r--   1 lgwd     staff      2500 Aug 16 11:22 toprintlgwd.txt
-rw-r--r--   1 lgwd     staff      4224 Nov  3 09:19 tosend.txt
-rw-r--r--   1 lgwd     staff      4196 Nov  3 09:19 tosend.txt%
-rw-r--r--   1 lgwd     staff     12676 Aug 16 10:35 wmatext


gis1% pwd
/home/lgwd/temp/lisy  (Wetland coverages provided by DU)
gis1% ls -l
total 62
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 arena
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 arena-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 atwate
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 atwate-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:27 charle
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:27 charle-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 deltar
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 deltar-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 dospal
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 dospal-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 elnido
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 elnido-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 gustin
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 gustin-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 ingoma
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 ingoma-a
-rw-r--r--   1 lgwd     staff        81 Nov  8 02:10 log
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 losban
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 losban-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 newman
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 newman-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 sandym
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 sandym-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 sanluir
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 sanluir-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 stevin
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 stevin-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 turner
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 turner-a
drwxr-xr-x   2 lgwd     staff       512 Sep 28 13:28 volta
```

```
drwxr-xr-x   2 lgwd     staff        512 Sep 28 13:28 volta-a


/home/lgwd/amls
gis1% ls -l
total 332
-rw-r--r--   1 lgwd     staff       2097 Nov  7 21:46 1intro.aml
-rw-r--r--   1 lgwd     staff       2095 Nov  7 21:46 1intro.aml%
-rw-r--r--   1 lgwd     staff       7241 Nov  7 21:30 1present.aml
-rw-r--r--   1 lgwd     staff       7240 Nov  7 21:30 1present.aml%
-rw-r--r--   1 lgwd     staff       2325 Nov  1 13:16 2image.aml
-rw-r--r--   1 lgwd     staff       2321 Nov  1 13:16 2image.aml%
-rw-r--r--   1 lgwd     staff       3352 Oct  3 11:12 2present.aml
-rw-r--r--   1 lgwd     staff       3352 Oct  3 11:12 2present.aml%
-rw-r--r--   1 lgwd     staff        276 Aug 19 18:31 2t1precision2.aml
-rw-r--r--   1 lgwd     staff        842 Aug 19 18:31 2t1precision2.aml%
-rw-r--r--   1 lgwd     staff       1352 Aug 19 16:30 2to1precision
-rw-r--r--   1 lgwd     staff        842 Aug 19 16:30 2to1precision%
-rw-r--r--   1 lgwd     staff        842 Aug 19 16:23 2to1precision.aml
-rw-r--r--   1 lgwd     staff       2418 Oct  4 11:34 3close.aml
-rw-r--r--   1 lgwd     staff       2809 Oct  4 11:34 3close.aml%
-rw-r--r--   1 lgwd     staff       1641 Oct 13 17:42 4shorebird.aml
-rw-r--r--   1 lgwd     staff       1614 Oct 13 17:42 4shorebird.aml%
-rw-r--r--   1 lgwd     staff       1776 Oct  4 13:03 5mapfly.aml
-rw-r--r--   1 lgwd     staff       1776 Oct  4 13:03 5mapfly.aml%
-rw-r--r--   1 lgwd     staff       1545 Oct  4 14:10 6nddb.aml
-rw-r--r--   1 lgwd     staff       1629 Oct  4 14:10 6nddb.aml%
-rw-r--r--   1 lgwd     staff       1926 Nov  1 13:10 7lbgp.aml
-rw-r--r--   1 lgwd     staff        765 Nov  1 13:10 7lbgp.aml%
-rw-r--r--   1 lgwd     staff       1874 Nov  1 14:41 8biosph.aml
-rw-r--r--   1 lgwd     staff       1874 Nov  1 14:41 8biosph.aml%
-rw-r--r--   1 lgwd     staff       1963 Nov  7 15:39 8biospha.aml
-rw-r--r--   1 lgwd     staff       1926 Nov  7 15:39 8biospha.aml%
-rw-r--r--   1 lgwd     staff       1881 Nov  1 14:14 8sphere.aml
-rw-r--r--   1 lgwd     staff       1153 Nov  1 14:14 8sphere.aml%
-rwxrwxrwx   1 13108    staff         66 Jun 15 09:50 apnrel.aml
-rw-r--r--   1 lgwd     staff        405 Jul 25 22:18 build1.aml
-rw-r--r--   1 lgwd     staff       1041 Oct 13 17:47 clear.aml
-rw-r--r--   1 lgwd     staff        165 Oct 13 17:47 clear.aml%
-rw-r--r--   1 lgwd     staff       1187 Nov  1 17:10 clearif.aml
-rw-r--r--   1 lgwd     staff       1165 Nov  1 17:10 clearif.aml%
-rwxrwxrwx   1 lgwd     staff       1091 Jul 18 14:44 copy.aml
-rwxr-xr-x   1 lgwd     staff       1096 Jul 18 14:44 copy.aml%
-rw-r--r--   1 lgwd     staff       1085 Nov  1 16:40 copy2tape1.aml
-rw-r--r--   1 lgwd     staff       2562 Nov  1 18:30 copy2tape2.aml
-rw-r--r--   1 lgwd     staff       2674 Nov  1 18:30 copy2tape2.aml%
-rw-r--r--   1 lgwd     staff       1697 Nov  1 16:38 copytape1.aml
-rw-r--r--   1 lgwd     staff       1704 Nov  1 16:38 copytape1.aml%
-rw-r--r--   1 lgwd     staff       2817 Nov  1 17:41 copytape2.aml
-rw-r--r--   1 lgwd     staff       2817 Nov  1 17:41 copytape2.aml%
```

```
-rw-r--r--   1 lgwd     staff      1316 Aug 19 19:02 export.aml
-rw-r--r--   1 lgwd     staff      1314 Aug 19 19:02 export.aml%
-rw-r--r--   1 lgwd     staff      1341 Jul 26 00:58 export1.aml
-rw-r--r--   1 lgwd     staff       271 Aug 19 19:21 export2.aml
-rw-r--r--   1 lgwd     staff       350 Aug 19 19:21 export2.aml%
-rwxrwxrwx   1 13102    20         1911 May 19 09:10 flyloc.aml
-rwxrwxrwx   1 13102    20         1760 May 19 09:10 flyloc.aml%
-rw-r--r--   1 lgwd     staff       648 Sep 28 11:09 heading.aml
-rw-r--r--   1 lgwd     staff       756 Sep 28 11:09 heading.aml%
-rw-r--r--   1 root     other       361 Sep 27 18:14 intro.aml
-rw-r--r--   1 lgwd     staff       361 Sep 28 11:07 intro.aml%
-rw-r--r--   1 lgwd     staff      3441 Sep 30 16:44 intro1.aml%
-rw-r--r--   1 lgwd     staff       527 Oct 11 13:28 kill1011
-rw-r--r--   1 lgwd     staff       527 Oct 11 13:28 kill1011.aml
-rw-r--r--   1 lgwd     staff      1397 Sep 28 11:18 lgwdprsnt.aml
-rw-r--r--   1 lgwd     staff      1130 Sep 28 11:18 lgwdprsnt.aml%
-rw-r--r--   1 lgwd     staff       816 Aug 15 12:33 lutxt.aml
-rw-r--r--   1 lgwd     staff       847 Aug 15 12:33 lutxt.aml%
-rw-r--r--   1 lgwd     staff       534 Aug 12 15:33 nddbsym.aml
-rw-r--r--   1 lgwd     staff       843 Aug 12 15:33 nddbsym.aml%
-rw-r--r--   1 lgwd     staff       295 Aug 15 20:46 parcorrlu.aml
-rw-r--r--   1 lgwd     staff       286 Aug 15 20:46 parcorrlu.aml%
-rw-r--r--   1 lgwd     staff      3310 Sep 30 18:01 present.aml
-rw-r--r--   1 lgwd     staff      3306 Sep 30 18:01 present.aml%
-rw-r--r--   1 lgwd     staff       261 Aug 19 18:57 rename.aml
-rw-r--r--   1 lgwd     staff       363 Aug 19 18:57 rename.aml%
-rw-r--r--   1 lgwd     staff       948 Jul 24 14:32 rename1.aml
-rw-r--r--   1 lgwd     staff      1104 Jul 24 14:32 rename1.aml%
-rw-r--r--   1 lgwd     staff        22 Aug 28 12:36 rmvmaps.aml
-rw-r--r--   1 lgwd     staff        45 Aug 28 12:36 rmvmaps.aml%
-rw-r--r--   1 lgwd     staff       128 Nov  1 12:00 sp_utm.prj
-rw-r--r--   1 lgwd     staff       106 Nov  1 12:00 sp_utm.prj%
-rw-r--r--   1 lgwd     staff      1273 Aug 19 18:58 u2dscr
-rw-r--r--   1 lgwd     staff      1273 Aug 19 18:58 u2dscr%
-rw-r--r--   1 lgwd     staff      2620 Jul 23 16:59 utm.aml
-rw-r--r--   1 lgwd     staff      2677 Jul 23 16:59 utm.aml%
-rw-r--r--   1 lgwd     staff       663 Jul 23 18:05 utm2.aml


/home/lgwd/tape2/ludwr
gis1% ls -l
total 11716
-rw-r--r--   1 lgwd     staff    126304 Jul 22 14:25 lu3828.e00
-rw-r--r--   1 lgwd     staff    303813 Jul 22 14:26 lu3829.e00
-rw-r--r--   1 lgwd     staff    242076 Jul 22 14:26 lu3830.e00
-rw-r--r--   1 lgwd     staff    427243 Jul 22 14:26 lu3831.e00
-rw-r--r--   1 lgwd     staff    906203 Jul 22 14:27 lu3832.e00
-rw-r--r--   1 lgwd     staff    192711 Jul 22 14:28 lu3929.e00
-rw-r--r--   1 lgwd     staff    150142 Jul 22 14:28 lu3930.e00
-rw-r--r--   1 lgwd     staff    308194 Jul 22 14:28 lu3932.e00
```

```
-rw-r--r--   1 lgwd    staff    679852 Jul 22 14:29 lu3933.e00
-rw-r--r--   1 lgwd    staff    538810 Jul 22 14:29 lu4029.e00
-rw-r--r--   1 lgwd    staff    557514 Jul 22 14:29 lu4030.e00
-rw-r--r--   1 lgwd    staff    729274 Jul 22 14:30 lu4031.e00
-rw-r--r--   1 lgwd    staff    287119 Jul 22 14:31 lu4130.e00
-rw-r--r--   1 lgwd    staff    363610 Jul 22 14:31 lu4131.e00
-rw-r--r--   1 lgwd    staff      1938 Jul 22 14:32 reidlanduse.list
```

The USFWS map showing detailed info (regarding irrigation, shcedules, locations of ditches, etc) for all conservation easement properties remains in its DOS-AutoCAD format.

AML (ARC Macro Language) Scripts to generate maps for presentation.

```
/*  ________________________________________________________________
/*
/*     Program: 1intro.aml
/*     Purpose: Create intro1.map a duplicate of the first map,
/*              intro.aml, created by the present.aml script.
/*              It shows the geographical relationships between the
/*              gwma and the cities surrounding it.
/*  ________________________________________________________________
/*
/*     Inputs:
/*     Outputs:  screen output
/*               graphics file
/*
/*  ________________________________________________________________
/*
/*     History: 8/94 original coding, recoded 9/94 after erasure and
/*              backup recovery failure.
/*
/*
/*
/*  ________________________________________________________________
/*
&echo &on
&r offmaps
/*intro.map
/*image.map
/*shorebird.map
/*pblnds.map
/*nddb.map
/*lbgp.map
/*lglu.map
/*flymap.map
/*sph.map
imageview create tifvert size canvas 540 900 position 600 0
imageview create tifhori size canvas 1200 768 position ul
&pause
/*  intro.map begins the presentation by locating the geographical
/*  relationships between the gwma and the cities surrounding it.
map 1intro.map
mape gwmasa
lineset carto.lin
linesym 103
linecolor 3
arcs gwma
LINE 8.8 1.8 9.1 2.3 9.4 1.8  9.7 2.3
TEXTSIZE .3 .3
TEXTSET FONT.TXT
```

```
TEXTSYM 9
MOVE 9.9 2.1
TEXT 'GRASSLAND WILDLIFE'
MOVE 9.9 1.8
TEXT 'MANAGEMENT AREA'
linesym 201
arcs mroads
linesym 102
linecolor 7
arcs muni
textset font.txt
textsym 3
textsize .194 .194
move 5.6 3.4
text 'HWY 152'
textsize .15 .15
move 3.6 4.2
text 'HENRY MILLER ROAD'
textsize .15 .15
move 2.6 8.5
text 'HWY 140'
textsym 21
textsize .3 .3
move 6.95 1.65
text 'Dos Palos'
move 10 8.5
text 'Merced'
move 2.5 2.9
text 'Los Banos'
move 1.7 7.2
text 'Gustine'
lineset carto.lin
linesym 103
/*units map
/*line 727182 4090503 744884.94 4090503
/*text '5 MILES'
map end
```

```
/* ____________________________________________________________
/*
/*    Program:  2image.aml
/*    Purpose:  Display a color enhanced satellite view showing a
/*              regional view of the landscape.  Discuss two of the
/*              most important principles of conservation biology:
/*              AVOID FRAGMENTING HABITAT AND KEEP LINKS BETWEEN
/*              HABITAT PATCHES.
/*              Points to be made within the context of Conservation
/*              Biology are A) two major blocks of wetland habitat
/*              exist, one to the north and another to the south.
/*              These areas are identified by the enhanced colors
/*              blue = open water magenta = growing emergent vegetation,
/*              green = turbid water yellow = rice fields.   B) There
/*              is a natural corridor between the two areas, to the
/*              east of Los Banos, that provides a landscape linkage
/*              between them. c) This linkage is extremely important,
/*              it connects two areas of high biotic resource, greatly
/*              enhancing both of the biotic potential of each area.
/* ____________________________________________________________
/*
/*    Inputs:
/*    Outputs:  screen output
/*              graphics file
/*
/* ____________________________________________________________
/*
/*    History: 8/94 original coding, recoded 9/94 after erasure and
/*             backup recovery failure.
/*
/*
/*
/*____________________________________________________________
/*
mape gwmasa
image /home/lgwd/temp/t4334/t4334gras.gis
mape gwmasa
lineset carto.lin
linesym 103
linecolor 3
arcs gwma
units page
linesym 201
arcs mroads
linesym 102
linecolor 7
arcs muni94lb
textset font.txt
textsym 3
```

```
textsize .194 .194
units page
move 5.6 3.4
text 'HWY 152'
textsize .15 .15
move 3.6 4.2
text 'HENRY MILLER ROAD'
textsize .15 .15
move 2.6 8.5
text 'HWY 140'
textsize .4 .4
textsym 21
move 6.95 1.75
text 'Dos Palos'
move 10 8.5
text 'Merced'
move 2.5 2.9
text 'Los Banos'
move  0.677 6.95
text 'Gustine'
units map
linesym 104
box 720521.55 4088840.828 728568.285 4088840.828
move  721571.787  4086970.478
text '5 MILES'
msel 2 3 4 5 6 7 8 9 10 11 12 13
mdel
linecolor 5
arcs gwd
```

```
/* ________________________________________________________________
/*
/*   Program:  3close.aml
/*   Purpose:  To bring familiar photographic views of the landscape
/*             into close association with the satellite view by
/*             displaying a closeup of the a color enhanced
/*             satellite view (2image.map) and while toggling
/*             between the satellite view of the area and the
/*             relatively familiar photo views of the area.
/*
/* ________________________________________________________________
/*
/*   Notes:    Discussion with photos can include:
/*             a) lgwd-p01.tif - the old Pajaro Vista site with the
/*             fish ponds in the lower left next to HWY 152 and the
/*             reservoir below the sewage ponds(not visible) on edge
/*             of Santa Fe Grade.
/*             b) lgwd-p02.tif - the sewage ponds in the background
/*             and the latest development in the foreground.  To
/*             the east is more agriculture and wetland area.
/*             c) lgwd-p06.tif - Klamath duck club, northeast
/*             of the sewage ponds (in background), is optimum
/*             waterfowl habitat.
/*             d) lgwd-p10.tif - Open water habitat with emergent
/*             marsh.
/*             e) lgwd-p11.tif - Vast stretches of emergent fresh
/*             water marsh. Segue into multispecies management
/*             requirements (GGS)
/*
/*
/* ________________________________________________________________
/*
/*   Inputs:
/*   Outputs:  screen output
/*             graphics file
/*
/*
/* ________________________________________________________________
/*
/*   History: 8/94 original coding, recoded 9/94 after erasure and
/*            backup recovery failure.
/*
/*
/*
/*
/* ________________________________________________________________
/*
map close.map
imageview create tifvert size canvas 540 900 position 600 0
imageview create tifhori size canvas 1200 750 position ul
mape 688806.026 4108999.047 699751.038 4100824.923
image /home/lgwd/temp/t4334/t4334gras.gis
arcs mroads
```

```
textsize .194 .194
move 5.6 3.4
text 'HWY 152'
textsize .15 .15
move 3.6 4.2
text 'HENRY MILLER ROAD'
textsize .15 .15
imageview lgwd-p01.tif # # tifhori
&tty
imageview lgwd-p02.tif # # tifvert
&tty
imageview lgwd-p06.tif # # tifhori
&tty
imageview lgwd-p10.tif # # tifhori
&tty
imageview lgwd-p11.tif # # tifhori
map end
&tty
```

```
/*  ________________________________________________________________
/*
/*   Program:  4shorebird.aml
/*   Purpose:  Show relative shorebird diversity of the grassland
/*             area.
/*  ________________________________________________________________
/*
/*   Notes:    Two focal areas of high diversity are centered
/*             within each of the two wetland areas.
/*             To the east of Los Banos is a contiguious stretch
/*             of medium diversity linking the two high diversity
/*             patches.  To the west are lower diversity areas.
/*  ________________________________________________________________
/*   Inputs:
/*   Outputs:  screen output
/*             graphics file
/*  ________________________________________________________________
/*
/*   History: 8/94 original coding, recoded 9/94 after erasure and
/*            backup recovery failure.
/*  ________________________________________________________________
/*&if [exists /home/lgwd/shorebird.map -directory] &then
/*   &do
/*     &sys rm -r /home/lgwd/shorebird.map
/*   &end
/*&else
/*&do
/*&pause
/*&end
/*&pause
mape gwmasa
units page
map shorebird.map
SHADESET CARTO.SHD
polygonsh shorebird div shorebird.lut
textset font.txt
textsym 3
TEXTSIZE .5 .5
MOVE 7.96 7.55
TEXT 'SHOREBIRD DIVERSITY'
textsize .3 .3
KEYAREA 9.93 6.6 12.6 3.84
keyshade shorebird.lut info symbol text nobox
textsize .25 .25
move 9.36 2.55
text 'Raw data provided by'
move 9.36 2.08
text 'Point Reyes Bird Observatory'
map end
```

```
/* ________________________________________________________________
/*    Program:  5mapfly.aml
/*    Purpose:  Show area of pintail movement using Joe Fleskes
/*              pintail flight location data
/*
/* ________________________________________________________________
/*
/*    Notes:    Two focal areas of high diversity are centered
/*              within each of the two wetland areas.
/*              To the east of Los Banos is a contiguious stretch
/*              of medium diversity linking the two high diversity
/*              patches.  To the west are lower diversity areas.
/*
/* ________________________________________________________________
/*
/*    Inputs:
/*    Outputs:  screen output
/*              graphics file
/*
/* ________________________________________________________________
/*
/*    History: 8/94 original coding, recoded 9/94 after erasure and
/*             backup recovery failure.
/* ________________________________________________________________
mape gwma
map 5prnt.map
linecolor 6
arcs gwma
textsize .26 .26
lineset carto.lin
linesym 103
linecolor 7
arcs flyloc
line 10.2 6.1 10.35 6.7 10.5 6.1 10.65 6.7
move 10.8 6.24
text 'Pintail flight movements'
move 10.8 5.9
text 'on 3 hunt days, 1992'
linesym 108
linecolor 5
arcs gwd
line 10.2 3.6 10.35 4.2 10.5 3.6 10.65 4.2
move 10.88 3.75
text 'GRASSLAND WATER'
move 11.42 3.43
text 'DISTRICT'
textsize .215 .215
move 10.88 5.5
text 'personal communication'
move 10.88 5.3
```

```
text 'Joe Fleskes'
move 10.88 5.1
text 'National Biological Survey'
move 10.88 4.9
text 'Dixon, CA'
arcs public
labeltext public text
map end
```

```
/*
/* ________________________________________________________________
/*
/*    Program:  6nddb.aml
/*    Purpose:  To show the endangered, threatened and rare species
/*              that are listed in the Natural Diversity
/*              Database.
/*
/* ________________________________________________________________
/*    Notes:    after the map is drawn, the identify command will
/*              allow the user to query 4 keymarker points.  If you
/*              pick the point in Los Banos be aware that
/*              there are numerous old (1931) records at that point.
/*              The  first record that will show is a yellow rail.
/* ________________________________________________________________
/*
/*    Inputs:
/*    Outputs:  screen output
/*              graphics file
/*
/* ________________________________________________________________
/*
/*    History: coded 9/94
/* ________________________________________________________________
&sys rm -r nddb.map
map nddb.map
linesym 101
linecolor 5
arcs canals
arcs hyd100k
linecolor 2
arcs mroads
linecolor 7
arcs muni
markerset municipal.mrk
pointmarker nddbshow cname nddbshow.lut
box 10.113 9.387 13.816 0.62
textsize .17 .17
textoffset 0 -.1
keyarea 10.113 9.387 13.816 0.62
keymarker nddbshow.lut info symbol cname nobox
textsize .22 .22
MOVE 10.175 0.320
text 'NATURAL DIVERSITY DATABASE 1994'
map end
identify nddbshow point *
identify nddbshow point *
identify nddbshow point *
identify nddbshow point *
```

```
/* ________________________________________________________________
/*
/*    Program:  7lbgp.aml
/*    Purpose:  To show the planned expansion of Los Banos in light
/*              of the previous information shown in the presentation
/*              script (1present.aml).
/*              The landuse plan of 8/94 is incompatible with the
/*              landuse requirements of the biological resources
/*              of Los Banos.  An area of resource benefical use
/*              and resource neutral use is identified for discussion
/*              purposes (hence not included in the legend).
/* ________________________________________________________________
/*
/*    notes:
/*map
/*
/* ________________________________________________________________
/*
/*    Program:  8biosph.aml
/*    Purpose:  To show the spheres of influence for the cities
/*              close to GWMA, and the one and two-mile spheres
/*              of the GWMA.
/*
/* ________________________________________________________________
/*
/*    Inputs:
/*    Outputs:  screen output
/*              graphics file
/*
/* ________________________________________________________________
/*
/*    History: 8/94 original coding, recoded 9/94 after erasure and
/*             backup recovery failure.
/* ________________________________________________________________
/*
map biosph.map
mape gwmasa
image /home/lgwd/temp/t4334/t4334gras.gis
shadeset color.shd
shadesym 1
units page
patch 10.09 9.5 13.92 0.04
textset font.txt
textsym 3
textcolor 0
textsize .4 .4
move 10.75 9.01
text "SPHERES OF"
```

```
MOVE 11 8.56
TEXT "INFLUENCE"
lineset carto.lin
textsym 3
textsize .3 .3
textcolor 0
linesym 202
arcs mroads
linesym 102
linecolor 0
arcs spheres
line 10.6 7 10.75 7.6 10.9 7.0 11.05 7.6
move 11.3 7.3
text "City Spheres"
linesym 103
linecolor 3
arcs gwma
line 10.6 6 10.75 6.6 10.9 6.0 11.05 6.6
move 11.3 6.4
text "Grassland Wildlife"
move 11.3 6.1
text "Management Area"
linecolor 5
arcs gwd
line 10.6 5 10.75 5.6 10.9 5.0 11.05 5.6
move 11.3 5.4
text "Grassland Water"
move 11.6 5.1
text "District"
move 11.3 4.4
text "GWMA 1 mile"
move 11.6 4.1
text "sphere"
linecolor 7
arcs gwmaone
arcs gwmasa
line 10.6 4 10.75 4.6 10.9 4.0 11.05 4.6
line 10.6 3 10.75 3.6 10.9 3.0 11.05 3.6
lineset oilgas.lin
linesym 102
linecolor 9
arcs gwmasa
line 10.6 3 10.75 3.6 10.9 3.0 11.05 3.6
move 11.3 3.4
text "GWMA 2 mile"
move 11.6 3.1
text "sphere"
map end
```

APPENDIX C. Data Transfer/ GWD Computer Implementation.

Three basic options exist for the transfer and use of the database developed by Thomas Reid Associates.

1. Use existing resources for map viewing and provide data tapes to researchers with ARC/INFO or other GIS system for working with files. This option will allow you to view and print the maps as a graphic file or import them into a graphic program (Aldus FREEHAND, MACPAINT) for further non-geographically referenced manipulation.

Cost: minimal (floppy discs and 2-3 1/4" tape drives @ $15/tape.)

2. Acquire pc ARCVIEW software from ESRI and a cd-rom and cd-rom drive. This option allows you to view and update the datafiles.

Cost: $150 CD ROM disc (additional CD ROM's @ $15 - 55/disc depending on quantity.
$200-400 CD ROM disc drive
$995 ARCVIEW for pc

3. Acquire pc ARC/INFO. This option allows you full manipulation of the data.

Cost: $3500

EXHIBIT 10

C.V. of Dr. Reed Noss

CURRICULUM VITAE

Reed Frederick Noss, Ph.D.
Conservation Biologist
Certified Senior Ecologist, Ecological Society of America
Fellow, American Association for the Advancement of Science

Office:
University of Central Florida
Department of Biology
4000 Central Florida Blvd.
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web page: http://www.cas.ucf.edu/biology/

Summary

Primary interests and talents are in conservation biology, biogeography, landscape ecology, vertebrate ecology, vegetation science, land-use planning, nature reserve design, ecosystem management, field ornithology and herpetology, forest and desert ecology, biological inventory and monitoring, natural history, teaching, writing, and editing.

Education includes a B.S. in Biology and Health Education, graduate work in Environmental Education, a M.S. in Ecology (University of Tennessee), and a Ph.D. in Wildlife Ecology (University of Florida).

Employment experience includes field biological research, animal and plant population surveys, conservation and land-use planning, environmental assessment and review, land management, natural history interpretation, supervision, research administration, writing, editing, and teaching. Professional service includes Editor-in-Chief, *Conservation Biology* (1993-1997) and President of the Society for Conservation Biology (1999-2001).

Personal

Born June 23, 1952, Dayton, Ohio (citizen of U.S.A.)
Married, three children
Excellent physical condition

Employment

August 2002-present. **Davis-Shine Professor of Conservation Biology and Provost's Distinguished Research Professor**, University of Central Florida, Department of Biology, Orlando, FL

February 2002 – present. **Chief Scientist**, The Wildlands Project, Richmond, Vermont

August 1990-present. **International Consultant and Lecturer in Conservation Biology**

August 1999-2002. **Chief Scientist**. Conservation Science, Inc. Corvallis, OR, and Chuluota, FL

2000-present. **Adjunct Professor and Courtesy Professor**. Department of Biology, University of Oregon. Eugene, Oregon

1997-present. **Courtesy Professor**, Department of Forest Science, Oregon State University, Corvallis, Oregon

1994-present. **Courtesy Associate Professor,** Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon

1989-present. **Adjunct Professor,** The Union Institute, University of Cincinnati, Cincinnati, Ohio

August 1997-August 1999. **Chief Scientist,** The Conservation Biology Institute. Corvallis, Oregon

1993-1997. **Editor**, *Conservation Biology*. Society for Conservation Biology. Oregon State University, Department of Fisheries and Wildlife, Corvallis, Oregon

1991-1997. **Research Associate**, Stanford University, Center for Conservation Biology

1991-1996. **Research Scientist**, University of Idaho, College of Forestry (half-time appointment, National Biological Service; on leave Sept. 1993-May 1996 as a Pew Scholar in Conservation)

1992-1996. **Science Director**, The Wildlands Project (supported by Pew Scholars Award in Conservation and the Environment)

1989-1994. **Courtesy Assistant Professor,** Department of Fisheries and Wildlife, Oregon State University

1988-1990. **Biodiversity Project Leader**, U.S. Environmental Protection Agency, Environmental Research Lab, Corvallis, Oregon

1984-1988. **President and Ecologist,** Landscape Ecosystems (consulting firm), Gainesville, Florida

1987-1988. **Staff Ecologist**, KBN Engineering & Applied Sciences, Inc., Gainesville, Florida

1988. **Adjunct Faculty**, Santa Fe Community College, Gainesville, Florida (Biology Instructor)

1987. **Associate Faculty**, School for Field Studies, Beverly, Massachusetts (taught field ecology course in San Juan Mountains of Colorado)

1984-1987. **Graduate Research Assistant**, University of Florida, Gainesville, FL

1983-1984. **Managed Area Specialist**, Florida Natural Areas Inventory, The Nature Conservancy, Tallahassee, FL

1981-1983. **Ecologist**, Ohio Natural Heritage Program, Ohio Dept. of Natural Resources, Division of Natural Areas & Preserves, Columbus, Ohio

1980-1981. **Naturalist**, Ohio Dept. of Natural Resources, Div. of Parks & Recreation

1979. **Field Biologist;** contracts included: (1) survey of herpetofauna in proposed state natural areas for Tennessee Natural Heritage Program; (2) survey of gray bat maternity colonies in Kentucky for U.S. Fish & Wildlife Service

1977-1979. **Graduate Teaching Assistant**, University of Tennessee (Knoxville); taught General Biology and General Ecology

1978. **Ecological Consultant in Nicaragua**. Land-use and national park planning

1972-1977. **Environmental Education**, several jobs: (1) Science Director for youth camp in Ontario (3 summers); (2) Teacher-naturalist at Glen Helen Outdoor Education Center, Antioch College (1 year); (3) Naturalist for youth camp in Ohio (1 summer); (4) Naturalist for Ohio Historical Society at Cedar Bog State Preserve (2.5 years, part-time)

Education

1975. B.S. School of Education, University of Dayton, Ohio. Final GPA = 3.78

1975-1976. Graduate School of Education, Antioch College, Yellow Springs, Ohio. 15 graduate hours in outdoor education

1979. M.S. Graduate Program in Ecology, University of Tennessee, Knoxville. Cumulative GPA = 3.96

1988. Ph.D. Department of Wildlife & Range Sciences, School of Forest Resources & Conservation, University of Florida. Cumulative GPA = 4.00

Honors and Awards

1984-1987. Graduate Research Award, School of Forest Resources and Conservation, University of Florida

1985. Annual Research Award, Florida Ornithological Society

1986. Annual Research Award, Alachua Audubon Society

1986. Annual Research Award, Frank M. Chapman Memorial Fund, American Museum of Natural History

1986. Annual Research Award, Josselyn Van Tyne Memorial Fund, American Ornithologists' Union

1987. President's Recognition Award, University of Florida

1988. Environmental Publication Award, National Wildlife Federation

1993-1996. Pew Scholars Fellowship in Conservation and the Environment

1995. Conservation Community Award for Outstanding Achievement in the Field of Publications, Natural Resources Council of America (for Noss and Cooperrider, *Saving Nature's Legacy*)

1995. Edward T. LaRoe III Memorial Award of the Society for Conservation Biology. This is the highest award of the Society, given for outstanding achievement in translating the principles of conservation biology to policy and management

1999. Elected Scientific Fellow, Wildlife Conservation Society

2001. Certified Senior Ecologist, Ecological Society of America

2001. Elected Fellow, American Association for the Advancement of Science

2002. Wildlife Publications Award, Outstanding Edited Book Category, The Wildlife Society (for Maehr, Noss, and Larkin, *Large Mammal Restoration*)

Avocations

Karate (6th degree black belt and master instructor, Hayashi-ha Shito-ryu), kobudo (ancient Okinawan weaponry, 3rd degree black belt), tai chi chu'an, hatha yoga, archery, birding, natural history, hiking and backpacking, canoeing, nature photography, music

Professional Society Memberships

Society for Conservation Biology
Ecological Society of America
American Association for the Advancement of Science
American Institute of Biological Sciences
Society for Ecological Restoration
The Natural Areas Association
Florida Ornithological Society
Florida Native Plant Society
Gopher Tortoise Council

Professional Appointments and Service

2002-present. Member, Florida Forever Work Group, Florida Natural Areas Inventory, Florida State University (Tallahassee, FL)

2002-present. Member, Brevard County Conservation Working Group (Brevard County, FL)

1998-present. Consulting Editor, *Conservation Biology*

2003. Leader, Science Advisory Panel, Mendocino Redwoods Natural Community Conservation Plan and Habitat Conservation Plan (Mendocino County, CA)

2002-2003. Member, Science Advisory Committee, Northeastern U.S. and Maritime Canada Conservation Plan, The Wildlands Project (Burlington, VT)

2002. Leader, Science Advisory Panel, Solano County Natural Community Conservation Plan and Habitat Conservation Plan (Solano County Water Agency, CA)

2002. Leader, Science Advisory Panel, Eastern Merced County Natural Community Conservation Plan and Habitat Conservation Plan (Merced Co., CA)

2001. Leader, Science Review Team, North San Diego County Multi-Species Conservation Plan (San Diego, CA)

2001. Leader, Science Advisory Team, Coachella Valley Multiple Species Habitat Conservation Plan, The Nature Conservancy, U.S. Fish and Wildlife Service, and Coachella Valley Mountains Conservancy, Palm Desert, CA

2000-2002. Chair, Forest Work Group and Member, Design Committee. State of the Nation's Ecosystems project, The H. John Heinz III Center for Science, Economics, and the Environment, Washington, D.C.

1999-2001. President, Society for Conservation Biology

2000-2001. Member, Advisory Panel for Implementation of "High Conservation Value Forests" and "The Precautionary Principle," Forest Stewardship Council, Oaxaca, Mexico

1999-2001. Scientific Advisor, Pima County Habitat Conservation Plan, Tucson, AZ

1997-1999. Leader. Science Team for Master Plan. Save-the-Redwoods League, San Francisco, CA

1998-2000. Leader. Scientific Panel for Review of Material Relevant to the Occurrence, Ecosystem Role, and Tested Management Options for Mountain Goats in Olympic National Park. U.S. Department of Interior

1999. Chair. Kanab Ambersnail Scientific Review Panel. Arizona Department of Game and Fish

1992-present. Member, Board of Governors, Society for Conservation Biology

1991-1996, 1999, 2000-present. Co-founder and Member of Board of Directors, The Wildlands Project

1990-present. Member, State of Oregon Habitat Conservation Trust Fund Board

1997-present. Member, Advisory Board, Korea Peace Bioreserves Project

1996-present. Science Advisor, World Resources Institute

1992-present. Member, Advisory Board, The Ecoforestry Institute

1992-present. Member, Scientific Advisory Board, Conservation International

1993-present. Member, Advisory Board, Oregon Natural Desert Association

1994-present. Member, Science Advisory Board, Defenders of Wildlife

1992-2000. Member, Board of Directors, Wild Earth Society

1993-1996. Member, Board of Directors, Natural Areas Association

1993. Member, Old-growth Ecosystem Panel for Northwest Forest Ecosystem Team advising President Clinton on forest management options

1993-1996. Member, Committee on the Scientific Basis for Ecosystem Management, Ecological Society of America

1994-1996. Member, Ad Hoc Committee to Revise Criteria for Selection of Biosphere Reserves, USMAB, U.S. Department of State

1991-1994. Member, Southern California Coastal Sage Scrub Scientific Review Panel (appointed by Governor of California)

1989-1991. Professional Participant, Keystone Center National Policy Dialogue on Biological Diversity

1990-1991. Member, World Wildlife Fund Advisory Committee on Habitat Conservation Plans

1989-present. Member, Advisory Board, Northwest Ecosystem Alliance

1991-present. Member, Board of Editors, Conservation Biology

1988-1993. Subject Matter Editor for Landscape Ecology, Board of Editors, The Natural Areas Journal

1991-present. Science Editor, Wild Earth

1984-present. Peer reviewer for Conservation Biology, Biological Conservation, Ecology, Ecological Applications, Journal of Wildlife Management, The Natural Areas Journal, BioScience, The Environmental Professional, Trends in Ecology and Evolution, Landscape Ecology, Ecography, and others

Courses Taught

School for Field Studies: Field Ecology in San Juan Mountains (co-taught), 1987
University of Florida: Field Techniques in Wildlife Ecology (co-taught), 1988
Santa Fe Community College: General Biology, 1988
U.S. Bureau of Land Management, U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. National Park Service: many short-courses on biodiversity, endangered species, and ecosystem management (co-taught), 1988-1999
Oregon State University: Seminar in Conservation Biology, 1994
University of Oregon: Conservation Biology, 2000
University of Central Florida: Seminar in Conservation Biology, 2003

Invited Lectures, Seminars, and Presentations

Average of 2-3 monthly since 1990 (i.e., too numerous to list).

Graduate Theses and Dissertations Supervised

1997 Carlos Carroll. Predicting the distribution of the fisher (*Martes pennanti*) in northwestern California, U.S.A. using survey data and GIS modeling. M.S., Department of Fisheries and Wildlife, Oregon State University.

1999 Kenneth W. Vance-Borland. Physical habitat classification for conservation planning in the Klamath Mountains region. M.S., Department of Fisheries and Wildlife, Oregon State University.

2000 Carlos Carroll. Spatial modeling of carnivore distribution and population viability. Ph.D., Department of Forest Science, Oregon State University.

2002 Paul Adamus. Winter habitat relationships of birds in wetlands in the Willamette Valley, Oregon. Ph.D., Department of Fisheries and Wildlife, Oregon State University.

Expected 2003: Robin Bjork. Intratropical migration of the Mealey Parrot (*Amazona farinosa*) in Guatemala: implications for conservation. Ph.D., Department of Fisheries and Wildlife, Oregon State University.

Major (> $100,000) Grant-Funded Projects Directed as Principal Investigator Since 1995

1995-1999. $170,000. Conservation Plan for Klamath-Siskiyou Ecoregion. Funders: W. Alton Jones Foundation, David and Lucille Packard Foundation, Foundation for Deep Ecology

1997-2002. $343,000. Rocky Mountain Carnivores Conservation Assessment. Funders: World Wildlife Fund Canada, The Nature Conservancy, Yellowstone to Yukon Conservation Initiative, Kendall Foundation, Wilburforce Foundation

1999-2001. $215,000. Conservation Assessment for Greater Yellowstone Ecosystem and Utah-Wyoming Rocky Mountains Ecoregion. Funders: The Nature Conservancy, Greater Yellowstone Coalition, Doris Duke Foundation

Professional References

Dr. Larry D. Harris, Professor Emeritus, Department of Wildlife Ecology and Conservation, Newins-Ziegler Hall, University of Florida, Gainesville, FL 32667, (352)495-6485, ldh@GNV.IFAS.UFL.EDU

Dr. Malcolm L. Hunter, Jr., Department of Wildlife Ecology, University of Maine, Orono, ME 04469-5755, (207) 581-2865, hunter@umenfa.maine.edu

Dr. Gary Meffe, Editor, *Conservation Biology*, Department of Wildlife Ecology and Conservation, Newins-Ziegler 303, Box 110430, University of Florida, Gainesville, FL 32667, (352) 846-0557, meffe@gnv.ifas.ufl.edu

Mr. Michael O'Connell, The Nature Conservancy, 1400 Quail Street S-130, Newport Beach, CA 92660, (949) 380-4174, mao4@pacbell.net, moconnell@tnc.org

Dr. John G. Robinson, Wildlife Conservation Society, 2300 Southern Blvd., Bronx, NY 10460 (718) 220-7165, WildCons@aol.com

Dr. J. Michael Scott, Idaho Cooperative Fish and Wildlife Research Unit, College of Forestry, University of Idaho, Moscow, ID, 83843 (208) 885-6960, mscott@uidaho.edu.

Dr. David Wilcove, Woodrow Wilson School, Robertson Hall, Princeton University, Princeton, NJ 08544, (609) 258-7118, dwilcove@princeton,edu

PUBLICATIONS

Publication Summary

Refereed Journal Articles: 46
Book Chapters: 47
Books: 5

Technical Reports and Symposium Proceedings: 53
Other Articles (essays, editorials, book reviews, etc.): 63
Total: 214

Refereed Journal Articles

Noss, R.F. 1981. The birds of Sugarcreek, an Ohio nature reserve. Ohio Journal of Science 81:29-40.

Noss, R.F., and S. McKee. 1983. The breeding birds of Mohican. The Ohio Cardinal 4(2):37-40.

Noss, R.F. 1983. Different levels of natural areas thinking. The Natural Areas Journal 3(3): 8-14.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. BioScience 33:700-706.

Noss, R.F. 1985. On characterizing presettlement vegetation: how and why. The Natural Areas Journal 5(1):5-19.

Noss, R.F., and L.D. Harris. 1986. Nodes, networks, and MUM's: preserving diversity at all scales. Environmental Management 10:299-309.

Noss, R.F. 1987. From plant communities to landscapes in conservation inventories: a look at The Nature Conservancy (USA). Biological Conservation 41:11-37.

Noss, R.F. 1987. Corridors in real landscapes: a reply to Simberloff and Cox. Conservation Biology 1:159-164.

Noss, R.F. 1987. Protecting natural areas in fragmented landscapes. The Natural Areas Journal 7 (1):2-13.

Noss, R.F. 1989. Longleaf pine and wiregrass: Keystone components of an endangered ecosystem. The Natural Areas Journal 9:211-213.

Noss, R.F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology 4:355-364.

Noss, R.F. 1991. Effects of edge and internal patchiness on avian habitat use in an old-growth Florida hammock. Natural Areas Journal 11:34-47.

Hirth, D.H., L.D. Harris, and R.F. Noss. 1991. Avian community dynamics in a peninsular Florida longleaf pine forest. Florida Field Naturalist 19(2):33-48.

Noss, R.F. 1991. Wilderness recovery: Thinking big in restoration ecology. The Environmental Professional 13:225-234.

Hughes, R.M., and R.F. Noss. 1992. Biological diversity and biological integrity: Current concerns in lakes and streams. Fisheries 17(3):11-19.

O'Connell, M.A., and R.F. Noss. 1992. Private land management for biodiversity conservation. Environmental Management 16:135-151.

Frissell, C.A., R.K. Nawa, and R. Noss. 1992. Is there any conservation biology in "New Perspectives?": A reply to Salwasser. Conservation Biology 6:461-464.

Scott, J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.C. Edwards, J. Ulliman, and R.G. Wright. 1993. Gap Analysis: A geographic approach to protection of biological diversity. Wildlife Monographs 123:1-41.

Noss, R.F. 1993. A conservation plan for the Oregon Coast Range: Some preliminary suggestions. Natural Areas Journal 13:276-290.

Kremen, C., R. Colwell, T.L. Erwin, D.D. Murphy, R.F. Noss, and M.A. Sanjayan. 1993. Arthropod assemblages: Their use as indicators in conservation planning. Conservation Biology 7: 796-808.

Atwood, J.L., and R.F. Noss. 1994. Gnatcatchers and natural community conservation planning: Have we really avoided a train wreck? Illahee: Journal of the Northwest Environment 10:123-130.

Noss, R.F. 1994. Some principles of conservation biology, as they apply to environmental law. Chicago Kent Law Review 69:893-909.

Noss, R.F. 1996. Biodiversity, ecological integrity, and wilderness. International Journal of Wilderness 2(2):5-8.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J.F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parsons, C.H. Peterson, M.G. Turner, and R.G. Woodmansee. 1996. The report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. Ecological Applications 6:665-691.

Noss, R.F., H.B. Quigley, M.G. Hornocker, T. Merrill, and P. Paquet. 1996. Conservation biology and carnivore conservation. Conservation Biology 10:949-963.

DellaSala, D., J.R. Strittholt, R.F. Noss, and D.M. Olson. 1996. A critical role for core reserves in managing Inland Northwest landscapes for natural resources and biodiversity. Wildlife Society Bulletin 24:209-221.

Kiester, A.R., J.M. Scott, B. Csuti, R. Noss, B. Butterfield, K. Sahr, and D. White. 1996. Conservation prioritization using GAP data. Conservation Biology 10:1332-1342.

Noss, R.F. 1996. On attacking a caricature of reserves: response to Everett and Lehmkuhl. Wildlife Society Bulletin 24:777-779.

Beier, P., and R.F. Noss. 1998. Do habitat corridors provide connectivity? Conservation Biology 12:1241-1252.

Noss, R.F. 1999. Assessing and monitoring forest biodiversity: a suggested framework and indicators. Forest Ecology and Management 115:135-146.

Noss, R.F. 1999. Is there a special conservation biology? Ecography 22:113-122.

Noss, R.F. 1999. Aldo Leopold was a conservation biologist. Wildlife Society Bulletin 26:713-718.

Noss, R.F., J. R. Strittholt, K. Vance-Borland, C. Carroll, and P. Frost. 1999. A conservation plan for the Klamath-Siskiyou ecoregion. Natural Areas Journal 19:392-411.

Carroll, C., W. J. Zielinski, and R.F. Noss. 1999. Using presence-absence data to build and test spatial habitat models for the fisher in the Klamath region, USA. Conservation Biology 13:1344-1359.

Main, M.B., F.M. Roka, and R.F. Noss. 1999. Incentive-based conservation on private lands in southwest Florida. Conservation Biology 13:1262-1272.

DellaSala, D.A., R.F. Noss, and D. Perry. 2000. Applying conservation biology and ecosystem management to federal lands and forest certification. Ecoforestry 15(2):28-39.

Noss, R.F. 2000. High-risk ecosystems as foci for considering biodiversity and ecological integrity in ecological risk assessments. Environmental Science and Policy 3:321-332.

Noss, R.F. 2001. Beyond Kyoto: Forest management in a time of rapid climate change. Conservation Biology 15:578-590.

Carroll, C., R.F. Noss, and P.C. Paquet. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. Ecological Applications 11:961-980.

Andreasen, J.K., R.V. O'Neill, R. Noss, and N.C. Slosser. 2001. Considerations for the development of a terrestrial index of ecological integrity. Ecological Indicators 1:21-35.

Noss, R.F., C. Carroll, K. Vance-Borland, and G. Wuerthner. 2002. A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone Ecosystem. Conservation Biology 16:895-908.

Redford, K.H. P. Coppolillo, E.W. Sanderson, G.A.B. da Fonseca, E. Dinerstein, C. Groves, G. Mace, S. Maginnis, R. Mittermeier, R. Noss, D. Olson, J.G. Robinson, A. Vedder, and M. Wright. 2003. Mapping the conservation landscape. Conservation Biology 17:116-131

Carroll, C., R.F. Noss, P.C. Paquet, and N.H. Schumaker. In press. Integrating population viability analysis and reserve selection algorithms into regional conservation plans. Ecological Applications.

Noss, R.F. 2003. A checklist for wildlands network designs. Conservation Biology 17:xx-xx.

Noss, R.F. In review. Information needs for large-scale conservation planning. Natural Areas Journal.

Carroll, C., R.F. Noss, P.C. Paquet, and N.H. Schumaker. In review. Extinction debt of protected areas in developing landscapes. Conservation Biology.

Books

Noss, R.F., and A. Cooperrider. 1994. Saving Nature's Legacy: Protecting and Restoring Biodiversity. Island Press, Washington, D.C.

Noss, R.F., M.A. O'Connell, and D.D. Murphy. 1997. The Science of Conservation Planning: Habitat Conservation under the Endangered Species Act. Island Press, Washington, D.C.

Noss, R.F., editor. 2000. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, D.C.

Pimentel, D., L. Westra, and R. Noss, editors. 2000. Ecological Integrity: Integrating Environment, Conservation, and Health. Island Press, Washington, D.C.

Maehr, D., R. Noss, and J. Larkin, editors. 2001. Large Mammal Restoration: Ecological and Sociological Challenges for the 21st Century. Island Press, Washington, D.C.

Book Chapters (Peer-Reviewed)

Henderson, S., R.K. Olson, and R.F. Noss. 1989. Current and potential threats to biodiversity in forests of the Lower Pacific Coastal States. Pages 325-336 in R.K. Olson and A.S. Lefohn, eds. Effects of Air Pollution on Western Forests. Air and Waste Management Association, Pittsburgh, PA.

Duever, L.C., and R.F. Noss. 1990. A computerized method of priority ranking for natural areas. Pages 22-33 in R.S. Mitchell, C.J. Sheviak, and D.J. Leopold, eds. Ecosystem Management: Rare Species and Significant Habitats. Bulletin No. 471, New York State Museum, Albany, NY.

Noss, R.F. 1990. What can wilderness do for biodiversity? Pages 49-61 in P. Reed, ed. Preparing to Manage Wilderness in the 21st Century. USDA Forest Service, Southeastern Forest Experiment Station, Asheville, NC.

Noss, R.F., and M.J. Bland. 1990. Geology and physiography. Pages 4-26 in S.H. Wolfe, ed. An Ecological Characterization of the Florida Springs Coast: Pithlachascotee to Waccasassa Rivers. Biological Report 90(21). USDI Fish and Wildlife Service, Washington, DC.

Noss, R.F., and S.H. Wolfe. 1990. Summary. Pages 211-219 in S.H. Wolfe, ed. An Ecological Characterization of the Florida Springs Coast: Pithlachascotee to Waccasassa Rivers. Biological Report 90(21). USDI Fish and Wildlife Service, Washington, DC.

Noss, R.F. 1991. From endangered species to biodiversity. Pages 227-246 in K. Kohm, editor. Balancing on the Brink of Extinction: The Endangered Species Act and Lessons for the Future. Island Press, Washington, DC.

Noss, R.F. 1991. Landscape connectivity: Different functions at different scales. Pages 27-39 in W.E. Hudson, ed. Landscape Linkages and Biodiversity. Island Press, Washington, DC.

Barker, J.R., S.H. Henderson, R.F. Noss. and and D.T. Tingey. 1991. Biodiversity and human impacts. Pages 353-362 in Encyclopedia of Earth System Science, Vol. 1. Academic Press, San Diego, CA.

Noss, R.F. 1992. Issues of scale in conservation biology. Pages 239-250 in P.L. Fiedler and S.K. Jain, eds. Conservation Biology: The Theory and Practice of Nature Conservation, Preservation, and Management. Chapman and Hall, New York.

Noss, R.F., S.P. Cline, B. Csuti, and J.M. Scott. 1992. Monitoring and assessing biodiversity. Pages 67-85 in E. Lykke, ed. Achieving Environmental Goals: The Concept and Practice of Environmental Performance Review. Belhaven Press, London, England.

Noss, R.F. 1992. Interpreting biodiversity. Pages 11-37 in W.E. Hudson, ed. Nature Watch: A Resource for Enhancing Wildlife Viewing Areas. Defenders of Wildlife and Falcon Press, Helena, MT.

Noss, R.F. 1993. Wildlife corridors. Pages 43-68 in D.S. Smith and P.C. Hellmund, eds. Ecology of Greenways. University of Minnesota Press, Minneapolis, MN.

Henderson, S., R.F. Noss, and P. Ross. 1993. Can NEPA protect biodiversity? Pages 463-472 in S.G. Hildebrand and J.B. Cannon, eds. Environmental Analysis: The NEPA Experience. Lewis, Boca Raton, FL.

Grumbine, R.E., M. Friedman, and R.F. Noss. 1993. Conserving biodiversity in the Greater North Cascades Ecosystem. Pages 136-155 in M. Friedman and P. Lindholdt, eds. Cascadia Wild. Greater Ecosystem Alliance and Frontier Publishing, Seaside, OR.

Noss, R.F. 1993. A sustainable forest is a diverse and natural forest. Pages 33-39 in B. Devall, ed. Clearcut: The Tragedy of Industrial Forestry. Sierra Club Books and Earth Island Press, San Francisco, CA.

Noss, R.F. 1993. Sustainable forestry or sustainable forests? Pages 17-43 in G.H. Aplet, N. Johnson, J.T. Olson, and V.A. Sample, eds. Defining Sustainable Forestry. The Wilderness Society and Island Press, Washington, DC.

Noss, R.F., and B. Csuti. 1994. Habitat fragmentation. Pages 237-264 in G.K. Meffe and R.C. Carroll, eds. Principles of Conservation Biology. Sinauer Associates, Sunderland, MA.

Noss, R.F. 1994. Creating regional reserve networks. Pages 289-290 in G.K. Meffe and R.C. Carroll, eds. Principles of Conservation Biology. Sinauer Associates, Sunderland, MA.

Noss, R.F. 1994. Hierarchical indicators for monitoring changes in biodiversity. Pages 79-80 in G.K. Meffe and R.C. Carroll, eds. Principles of Conservation Biology. Sinauer Associates, Sunderland, MA.

Noss, R.F. 1994. Biodiversity, wildness, and The Wildlands Project. Pages 34-42 in D.C. Burks, ed. Place of the Wild: A Wildlands Anthology. Island Press, Washington, DC.

Noss, R.F. 1995. Ecological integrity and sustainability: Buzzwords in conflict? Pages 60-76 in L. Westra and J. Lemons, eds. Perspectives on Ecosystem Integrity. Kluwer Academic Publications, Boston.

Kavanagh, K., R. Noss, and T. Iacobelli. 1995. Building the ark: the science behind the selection of protected areas. Pages 2-8 in M. Hummel, ed. Protecting Canada's Endangered Spaces: An Owner's Manual. Ken Porter Books, Toronto.

Noss, R.F. 1996. Conservation of biodiversity at the landscape scale. Pages 574-589 in R.C. Szaro and D.W. Johnston, eds. Biodiversity in Managed Landscapes. Oxford University Press, New York.

Noss, R.F. 1996. Protected areas: How much is enough? Pages 91-120 in R.G. Wright, ed. National Parks and Protected Areas. Blackwell, Cambridge, MA.

Noss, R.F., and J.M. Scott. 1997. Ecosystem protection and restoration: The core of ecosystem management. Pages 239-264 in M.A. Boyce and A.W. Haney, eds. Ecosystem Management: Concepts and Methods. Yale University Press, New Haven, CT.

Noss, R.F., and B. Csuti. 1997. Habitat fragmentation. Pages 269-304 in G.K. Meffe and R.C. Carroll, eds. Principles of Conservation Biology. Second edition. Sinauer Associates, Sunderland, MA.

Noss, R.F. 1997. Conservation assessments: a synthesis. Pages 95-99 in T. Ricketts, E. Dinerstein, D.M. Olson, C. Loucks, P. Hedao, P. Hurley, R. Abell, S. Walters, and K. Carney. A Conservation Assessment of the Terrestrial Ecoregions of North America. World Wildlife Fund, Washington, DC.

Noss, R.F. 1997. Principles of conservation biology. Pages 16-30 in L. Jenkins and J. Peepre, eds. Towards a Yukon Protected Areas Strategy: Applying thr Principles of Conservation Biology. Proceedings of a Workshop on Conservation Biology, Whitehorse, Yukon, May, 1996. Canadian Parks and Wilderness Society, Whitehorse, Yukon.

Terborgh, J., J.A. Estes, P. Paquet, K. Ralls, D. Boyd-Heger, B.J. Miller, and R.F. Noss. 1999. The role of top carnivores in regulating terrestrial ecosystems. Pages 39-64 in M.E. Soulé and J. Terborgh (eds.). Continental Conservation: Scientific Foundations of Regional Reserve Networks. Island Press, Washington, DC.

Noss, R.F., Dinerstein, B. Gilbert, M.. Gilpin, B. Miller, J. Terborgh, and S. Trombulak. 1999. Core areas: Where nature reigns. Pages 99-128 in M.E. Soulé and J. Terborgh (eds.). Continental Conservation: Scientific Foundations of Regional Reserve Networks. Island Press, Washington, DC.

Dobson, A., K. Ralls, M. Foster, M.E. Soulé, D. Simberloff, D. Doak, J.A. Estes, L.S. Mills, D. Mattson, R. Dirzo, H. Arita, S. Ryan, E.A. Norse, R.F. Noss, and D. Johns. 1999. Corridors: Reconnecting fragmented landscapes. Pages 129-170 in M.E. Soulé and J. Terborgh (eds.). Continental Conservation: Scientific Foundations of Regional Reserve Networks. Island Press, Washington, DC.

Noss, R.F. 1999. At what scale should we manage biodiversity? Pages 96-116 in F. Bunnell and J. Jackson, eds. The Living Dance: Policy and Practices for Biodiversity in Forest Landscapes. University of British Columbia Press, Vancouver, BC.

Noss, R. 1999. Conservation assessments: a synthesis. 1999. Pages 89-92 in T.H. Ricketts, E. Dinerstein, D.M. Olson, C.J. Loucks, W. Eichbaum, D. DellaSala, K. Kavanagh, P. Hedao, P.T. Hurley, K.M. Carney, R. Abell, and S. Walters. Terrestrial Ecoregions of North America: A Conservation Assessment. Island Press, Washington, DC.

Noss, R.F. 1999. Restoring grassland ecosystems: an opportunity to save the pieces. Pages 36-37 in B.L. Harper-Lore, ed. Roadside Use of Native Plants. U.S. Department of Transportation, Federal Highway Administration. Washington, DC.

Noss, R. 2000. More than big trees. Pages 1-6 in R. Noss, ed. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, DC.

Sawyer, J.O., J. Gray, G.J. West, D. Thornburgh, R.F. Noss, J.J. Engbeck, B. Marcot, and R. Raymond. 2000. History of redwood and redwood forests. Pages 7-38 in R. Noss, ed. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, DC.

Sawyer, J.O., S.C. Sillett, J.H. Popenoe, A. LaBanca, T. Sholars, D. Largent, F. Euphrat, R. Noss, and R. Van Pelt. 2000. Characteristics of redwood forests. Pages 39-79 in R. Noss, ed. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, DC.

Sawyer, J.O., S.C. Sillett, W.J. Libby, T.E. Dawson, J.H. Popenoe, D.L. Largent, R. Van Pelt, S.D. Viers, Jr., R.F. Noss, D.A. Thornburgh, and P. del Tredici. 2000. Redwood trees, communities, and ecosystems: a closer look. Pages 81-118 in R. Noss, ed. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, DC.

Cooperrider, A., R. Noss, H. Welsh, C. Carroll, W. Zielinski, D. Olson, K. Nelson, and B. Marcot. 2000. Terrestrial fauna of redwood forests. Pages 119-163 in R. Noss, ed. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, DC.

Noss, R., J. Strittholt, G. Heilman,, P. Frost, and M. Sorensen. 2000. Conservation planning in the redwoods region. Pages 201-228 in R. Noss, ed. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, DC.

Thornburgh, D., R. Noss, F. Euphrat, D. Angelides, C. Olson, A. Cooperrider, H. Welsh, and T. Roelofs. 2000. Managing redwoods. Pages 229-261 in R. Noss, ed. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, DC.

Noss, R. 2000. Lessons from the redwoods. Pages 263-268 in R. Noss, ed. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, DC.

Noss, R.F. 2000. Maintaining the ecological integrity of landscapes and ecoregions. Pages 191-208 in D. Pimentel, L. Westra, and R. Noss, editors. Ecological Integrity: Integrating Environment, Conservation, and Health. Island Press, Washington, DC.

Noss, R.F. 2001. Introduction: Why restore large mammals? Pages 1-21 in D. Maehr, R. Noss, and J. Larkin, eds. Large Mammal Restoration: Ecological and Sociological Challenges for the 21st Century. Island Press, Washington, DC.

Carroll, C., R. F. Noss, N. H. Schumaker, and P. C. Paquet. 2001. Is the return of the wolf, wolverine, and grizzly bear to Oregon and California biologically feasible? Pages 25-46 in D. Maehr, R. Noss, and J. Larkin, eds. Large Mammal Restoration: Ecological and Sociological Challenges for the 21st Century. Island Press, Washington, DC.

Noss, R.F. 2002. Aldo Leopold was a conservation biologist. Pages 106-117 in R.L, Knight and S. Riedel, eds. Aldo Leopold and the Ecological Conscience. Oxford University Press, Oxford, UK.

Noss, R.F., and K. Daly. In prep. Incorporating connectivity into broad-scale conservation planning. Chapter in K. Crooks and M. Sanjayan, editors. Maintaining connections for nature: the importance of connectivity for conservation.

Technical Reports and Symposium Proceedings

Noss, R.F. 198l. Birds of Ohio: a Field Checklist. Ohio Department of Natural Resources. 12 pp.

Noss, R.F., H.W. Kale, and C.W. Biggs. 1985. Florida Breeding Bird Atlas: Handbook for Cooperators. Florida Audubon Society, Maitland, Florida. 28 pp.

Noss, R.F. 1985. Landscape Considerations in Reintroducing and Maintaining the Florida Panther: Design of Appropriate Preserve Networks. Report to the Florida Panther Technical Advisory Council. 32 pp. + figures.

Cristoffer, C., R.F. Noss, and J.F. Eisenberg. 1985. Report No. 3. On the captive breeding and reintroduction of the Florida panther into suitable habitats. Report to Florida Game & Fresh Water Fish Commission, Tallahassee, FL.

Harris, L.D., and R.F. Noss. 1987. Endangerment with the best of intentions. Pages 31-38 in R. Fitter and M. Fitter, eds. Proceedings of a Symposium held by the Species Survival Commission, Madrid, 7-9 Nov., 1984. International Union for Conservation of Nature and Natural Resources, Gland, Switz.

Brown, M.T., J.M. Schaefer, K.H. Brandt, S.J. Doherty, C.D. Dove, J.P. Dudley, D.A. Eifler, L.D. Harris, R.F. Noss, and R.W. Wolfe. 1987. An Evaluation of the Applicability of Upland Buffers for the Wetlands of the Wekiva Basin. Center for Wetlands, University of Florida. 163 p.

Duever, L.C., R.W. Simons, R.F. Noss, and J.R. Newman. 1987. Comprehensive Inventory of Natural Ecological Communities in Alachua County. KBN Engineering and Applied Sciences. Gainesville, Florida.

Noss, R.F., and R.F. Labisky. 1988. Sensitivity of Vertebrates to Development in Four Upland Community Types in Northern Peninsular Florida. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.

Duever, L.C., and R.F. Noss, eds. 1990. Wiregrass Biology and Management: Maintaining Groundcover Integrity in Longleaf Pine Ecosystems. Proceedings of the Symposium, Oct. 13, 1988, Valdosta State College, GA. KBN Engineering and Applied Sciences, Inc. Gainesville, FL.

Scott, J.M., F. Davis, B. Csuti, B. Butterfield, R. Noss, S. Caicco, H. Anderson, J. Ulliman, F. D'Erchia, and C. Groves. 1990. Gap Analysis: Protecting Biodiversity Using Geographic Information Systems. U.S. Fish and Wildlife Service, Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, ID.

Noss, R.F., and L.D. Harris. 1990. Connectivity and conservation of biological diversity: Florida as a case history. Pages 131-135 in Proceedings of the 1989 Society of American Foresters National Convention, Spokane, WA, September 24-27. Society of American Foresters, Bethesda, MD.

Noss, R.F. 1991. Federal Land Management Alternatives for Westside Forests: Effects on Wildlife and Biological Diversity. The Wilderness Society, Washington, DC.

Noss, R.F. 1991. Protecting Habitats and Biological Diversity: Design of Regional Reserve Systems. National Audubon Society, New York.

Noss, R.F. 1991. A Critical Review of the U.S. Fish and Wildlife Service's Proposal to Establish a Captive Breeding Population of Florida Panthers, with Emphasis on the Population Reestablishment Issue. Fund for Animals, Washington, DC.

Noss, R.F. 1991. Policy directions and management options for high-intensity fire habitats: Comments in panel discussion. Pages 393-394 in High Intensity Fire in Wildlands: Management Challenges and Options. Proceedings of the 17th Tall Timbers Fire Ecology Conference, May 18-21, Tallahassee, Florida. Tall Timbers Research Station, Tallahassee, FL.

Noss, R.F. 1992. Biodiversity in the Blue Mountains: A framework for monitoring and assessment. Proceedings, Blue Mountains Biodiversity Conference, Whitman College, Walla Walla, WA, May 26-29, 1992.

Noss, R.F. 1992. Connectivity as a principle for regional conservation planning. Proceedings of the Workshop: Linkages, Corridors, and Connectivity. March 17-19, 1992. University of Florida, Gainesville, FL.

Noss, R.F. 1992. A Preliminary Biodiversity Conservation Plan for the Oregon Coast Range. Coast Range Association, Newport, OR.

Noss, R.F. 1992. Biodiversity: Many scales and many concerns. Pages 17-22 in H. Kerner, ed. Proceedings of the Symposium on Biodiversity of Northwestern California. Wildlands Resources Center, University of California, Berkeley, CA.

Noss, R.F. 1994. El Proyecto de Tierras Silvestres: Estrategia para la conservacíon de Áreas Naturales. Pages 323-365 in A. Vega, ed. Corredores Conservacionistas en la Región Centroamericana. Memorias de una Conferencia Regional auspiciada por el Proyecto Paseo Pantera. Heredia, Costa Rica, 17 al 20 de Septiembre de 1993. Tropical Research and Development, Gainesville, FL.

O'Leary, J.F., S.A. DeSimone, D.D. Murphy, P.F. Brussard, M.S. Gilpin, and R.F. Noss. 1994. Bibliographies on coastal sage scrub and related malacophyllous shrublands of other Mediterranean-type climates. California Wildlife Conservation Bulletin No. 10. California Department of Fish and Game, Sacramento, CA.

Noss, R.F. 1995. Maintaining Ecological Integrity in Representative Reserve Networks. World Wildlife Fund Canada, Toronto, Ont.

Noss, R.F., E.T. LaRoe, and J.M. Scott. 1995. Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation. Biological Report 28. USDI National Biological Service, Washington, DC.

Noss, R.F. 1995. Biodiversity and Landscape Ecology: Wetland Restoration Policy. Technical Report, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR.

Noss, R.F., and R.L. Peters. 1995. Endangered Ecosystems of the United States: A Status Report and Plan for Action. Defenders of Wildlife, Washington, DC.

Noss, R.F. 1997. A Big-Picture Approach to Forest Certification: A Report for World Wildlife Fund's Forests for Life Campaign in North America. World Wildlife Fund, Washington, DC.

Noss, R.F. 1997. The principles of conservation biology (in action). Pages 22-32 in S. Legault and K. Wiebe, eds. Connections: Proceedings of the First Conference on the Yellowstone to Yukon Conservation Initiative. Y2Y, Canmore, AB.

DellaSala, D.A., D.M. Olson, E. Dinerstein, W. Wettengel, R.F. Noss, and W.M. Eichbaum. 1997. Conservation status and importance of the Klamath-Siskiyou ecoregion. Pages 16-21 in J.K. Beigel, E.S. Jules, and B. Snitkin. 1997. Proceedings of the First Conference on Siskiyou Ecology. May 30-June 1, 1997. Siskiyou Regional Educational Project, Cave Junction, OR.

Vance-Borland, K., and R.F. Noss. 1997. An ecosystem classification and gap analysis of the Klamath-Siskiyou region. Pages 175-183 in J.K. Beigel, E.S. Jules, and B. Snitkin. 1997. Proceedings of the First Conference on Siskiyou Ecology. May 30-June 1, 1997. Siskiyou Regional Educational Project, Cave Junction, OR.

Noss, R.F. 1999. A citizen's guide to ecosystem management. Biodiversity Legal Foundation, Boulder, CO. (Distributed as Wild Earth Special Paper #3)

Noss, R.F., N.C. Slosser, J.R. Strittholt, and C. Carroll. 1999. Metrics of ecological integrity for terrestrial ecosystems and entire landscapes. U.S. Environmental Protection Agency, Washington, DC.

Noss, R.F. 1999. High-risk ecosystems as foci for considering biodiversity and ecological integrity in ecological risk assessments. U.S. Environmental Protection Agency, Washington, DC.

Strittholt, J.R., G.E. Heilman, and R.F. Noss. 1999. A GIS-based model for assessing conservation focal areas for the redwood ecosystem. Conservation Biology Institute, Corvallis, OR.

Strittholt, J.R., R.F. Noss, P.A. Frost, K. Vance-Borland, C. Carroll, and G. Heilman. 1999. A conservation assessment and science-based plan for the Klamath-Siskiyou ecoregion. Earth Designs Consultants, Inc. and Conservation Biology Institute, Corvallis, OR.

Carroll, C., P.C. Paquet, and R.F. Noss. 1999. Modeling carnivore habitat in the Rocky Mountain Region: A literature review and suggested strategy. World Wildlife Fund Canada, Toronto, Ontario.

Noss, R., M. Gordon, E. Hoagland, C. Lydeard, P. Mehlhop, and B. Roth. 1999. Report of Kanab Ambersnail Review Panel on Taxonomic, Ecological, and Translocation Issues Concerning the

Conservation of *Oxyloma* Snails in Arizona and Utah. Report to Arizona Game and Fish Department. Phoenix, AZ.

Carroll, C., R.F. Noss, and P.C. Paquet. 2000. Carnivores as focal species for conservation planning in the Rocky Mountain region. World Wildlife Fund Canada, Toronto, Ontario.

Noss, R.F., R. Graham, D. R. McCullough, F. L. Ramsey, J. Seavey, C. Whitlock, and M. P. Williams. 2000. Review of Scientific Material Relevant to the Occurrence, Ecosystem Role, and Tested Management Options for Mountain Goats in Olympic National Park. Report to U.S. Department of Interior, Washington, D.C.

Noss, R.F. 2000. Landscape species as conservation tools. Unpublished report. Wildlife Conservation Society, Bronx, New York.

Noss, R.F. 2000. Habitat fragmentation as a cumulative impact of winery expansion and other development in Napa County, California. Unpublished report. Sierra Club, San Francisco, CA.

Franklin, J., D. Perry, R. Noss, D. Montgomery, and C. Frissell. 2000. Simplified forest management to achieve watershed and forest health: a critique. Report of the Scientific Panel on Ecosystem Based Forest Management. National Wildlife Federation, Seattle, WA.

Noss, R.F. 2000. Wilderness biology and conservation: future directions. Pages 52-54 in D.N. Cole, S.F. McCool, W.A. Freimund, and J. O'Loughlin, compilers. Wilderness Science in a Time of Change Conference. Vol. I: Changing Perspectives and Future Directions. Proceedings RMRS-P-15-VOL-1.USDA Forest Service Rocky Mountain Research Station, Ogden, UT.

Noss, R..F. 2001. Biocentric ecological sustainability: A citizen's guide. Biodiversity Legal Foundation, Louisville, CO.

Noss, R., E. Allen, G. Ballmer, J. Diffendorfer, M. Soulé, R. Tracy, and R. Webb. 2001. Independent science advisors' review: Coachella Valley Multiple Species Habitat Conservation Plan (MSHCP/NCCP). Conservation Science, Inc., Corvallis, OR.

Noss, R., P. Beier, D. Faulkner, R. Fisher, B. Foster, T. Griggs, P. Kelly, J. Opdycke, T. Smith, and P. Stine. 2001. Independent science advisors' review: North County Subarea Plan, County of San Diego, Multiple Species Conservation Program. Part I: Review of habitat conservation model, with suggestions for conservation planning principles, species coverage, and adaptive management.

Noss, R.F., G. Wuerthner, K. Vance-Borland, and C. Carroll. 2001. A Biological Conservation Assessment for the Greater Yellowstone Ecosystem: Report to the Greater Yellowstone Coalition. Conservation Science, Inc., Corvallis, OR.

Noss, R.F., G. Wuerthner, K. Vance-Borland, and C. Carroll. 2001. A Biological Conservation Assessment for the Utah-Wyoming Rocky Mountains Ecoregion: Report to The Nature Conservancy. Conservation Science, Inc., Corvallis, OR.

Noss, R., P. Beier, D. Faulkner, R. Fisher, B. Foster, T. Griggs, P. Kelly, J. Opdycke, T. Smith, and P. Stine. 2002. Independent science advisors' review: North County Subarea Plan, County of San Diego, Multiple Species Conservation Program. Part II: Review of Consultants' Response to Part I Report and Revision of Preserve Planning Process. San Diego, CA.

Noss, R.F., K. Bennett, E. Butterworth, A. Couturier, P. Paquet, and K. Vance-Borland. 2002. Conservation Biology for Canada's Boreal Forest. Report to the Pew Foundation and the Canadian Boreal Trust. Conservation Science, Inc. Corvallis, OR.

Carroll, C., R.F. Noss, and P.C. Paquet. 2002. Rocky Mountain Carnivore Project Final Report. Report to World Wildlife Fund Canada. Conservation Science, Inc. Corvallis, OR.

Noss, R., R. Amundson, M. Barbour, R. Bugg, B. Cypher, R. Grosberg, T. Hanes, R. Hansen, B. Pavlik, K. Rice, P. Trenham, B. Shaffer, and B. Weir. 2002. Report of Science Advisors, Eastern Merced County Natural Community Conservation Plan and Habitat Conservation Plan. Part I: General Review of Approach, Methods, and Planning Principles, and Responses to Initial Questions. Merced, CA.

Noss, R., R. Amundson, D. Arnold, M. Bradbury, S. Collinge, B. Grewell, L. McKee, P. Northen, C. Swanson, and R. Yoshiyama. 2002. Report of Science Advisors, Solano County Natural Community Conservation Plan and Habitat Conservation Plan. Vacaville, CA.

Foreman, D., K. Daly, R.F. Noss, M. Clark, K. Menke, D. R. Parsons. R. Howard. 2003. New Mexico Highlands Wildlands Network Vision—Connecting the sky islands to the Southern Rockies. Wildlands Project, Richmond, VT.

Other Articles

Noss, R.F. 1980. Caving for gray bats in Kentucky. The Explorer 22(4): 22-27.

Noss, R.F. 1982. Conservation in and out of nature preserves. Ohio Journal of Science 82: 101.

Noss, R.F. 1983. Birds as preserve management indicators: regional perspective urged. Restoration and Management Notes 1(3): 29.

Noss, R.F. 1983. Re-creating an Ohio Valley wilderness. Midwest Earth Advocate 1(1): 4.

Noss, R.F. 1984. About not knowing everything (Guest Editorial). Restoration and Management Notes 2(1): 3.

Noss, R.F. 1985. Rescue or abuse? The Palmetto 4(4): 12.

Noss, R.F. 1986. Conservation Guidelines: Florida Native Plant Society. The Palmetto 6(2): 12-13.

Noss, R.F. 1986. Dangerous simplifications in conservation biology. Bulletin of the Ecological Society of America 67:278-279.

Noss, R.F. 1987. Do we really want diversity? Whole Earth Review 55: 126-128

Noss, R.F. 1987. Saving species by saving ecosystems: A review of The Preservation of Species: The Value of Biological Diversity, ed. by Brian G. Norton. Conservation Biology 1: 175-177.

Noss, R.F. 1987. Florida's National Forests: Our last chance.ENFO 87(6): 1-14.

Noss, R.F. 1988. The longleaf pine landscape of the Southeast: almost gone and almost forgotten. Endangered Species Update 5 (5): 1-8.

Noss, R.F. 1989. Who will speak for biodiversity? Conservation Biology 3: 102-103.

Noss, R.F., and S. Henderson. 1989. Biodiversity: A new focus for environmental protection. Habitat Futures, Summer 1989: 13-14.

Noss, R.F. 1989. A history of predator control. Review of Saving America's Wildlife, by T.R. Dunlap. Trends in Ecology and Evolution 4: 358.

Noss, R.F. 1990. Can we maintain biological and ecological integrity? Conservation Biology 4: 241-243.

Noss, R.F. 1991. Sustainability and wilderness. Conservation Biology 5: 120-122.

Noss, R.F. 1991. Review of Wildlife, Forests, and Forestry: Principles of Managing Forests for Biological Diversity, by Malcolm L. Hunter, Jr. Forest Perspectives 1(1): 18.

Noss, R.F. 1991/92. Biologists, biophiles, and warriors. Wild Earth 1(4): 56-60.

Brussard, P.F., D.D. Murphy, and R.F. Noss. 1992. Strategy and tactics for conserving biological diversity in the United States. Conservation Biology 6: 157-159.

Noss, R.F. 1992. The Wildlands Project: Land conservation strategy. Wild Earth (Special Issue): 10-25.

Foreman, D., J. Davis, D. Johns, R. Noss, and M. Soulé. 1992. The Wildlands Project mission statement. Wild Earth (Special Issue): 3-4.

Noss, R.F. 1993. Review of Nature Conservation 2: The Role of Corridors, by D.A. Saunders and R.J. Hobbs. Journal of Wildlife Management 57: 191-192.

Noss, R.F. 1993. Whither conservation biology? Conservation Biology 7: 215-217.

Murphy, D., D. Wilcove, R. Noss, J. Harte, C. Safina, J. Lubchenco, T. Root, V. Sher, L. Kaufman, M. Bean, and S. Pimm. 1994. On reauthorization of the Endangered Species Act. Conservation Biology 8: 1-3.

Noss, R.F. 1994. Cows and conservation biology. Conservation Biology 8: 613-616.

Noss, R.F. 1994/95. Wilderness--Now more than ever (A response to Callicott). Wild Earth 4(4): 60-63.

Noss, R.F. 1995. Foreword. Pages xiii-xv in L. Hansson, L. Fahrig, and G. Merriam, eds. Mosaic Landscapes and Ecological Processes. IALE Studies in Landscape Ecology 2. Chapman and Hall, New York.

Noss, R.F. 1995. Foreword. Pages x - x in CREILG Special Project Team. Atlas of the Central Rockies Ecosystem: Toward an Ecologically Sustainable Landscape. Komex International, Ltd., Calgary, Alberta.

Noss, R.F., and D.D. Murphy. 1995. Species and habitat are inseparable. Conservation Biology 9: 229-231.

Noss, R.F. 1995. The perils of Pollyannas. Conservation Biology 9: 701-703.

Noss, R.F. 1995. Assessing rigor and objectivity in conservation science. Wildlife Society Bulletin 23:539-541.

Noss, R.F. 1995/96. Science grounding strategy: Conservation biology in wildlands work. Wild Earth 5(4): 17-19.

Noss, R.F. 1995/96. What should endangered ecosystems mean to The Wildlands Project? Wild Earth 5(4): 20-29.

Vance-Borland, K., R. Noss, J. Strittholt, P. Frost, C. Carroll, and R. Nawa. 1995/96. A biodiversity conservation plan for the Klamath/Siskiyou region: A progress report on a case study for bioregional conservation. Wild Earth 5(4): 52-59.

Noss, R.F. 1996. The naturalists are dying off. Conservation Biology 10:1-3.

Noss, R.F. 1996. Do Eastside forests need restoration or crown fires? Wild Earth 6(2):9-11.

Noss, R.F. 1996. Foreword. Pages xi - xii in D.A. Falk, C.I. Millar, and M. Olwell, eds. Restoring Diversity: Strategies for Reintroduction of Endangered Plants. Center for Plant Conservation and Island Press, Washington, DC.

Noss, R.F. 1996. Ecosystems as conservation targets. Trends in Ecology and Evolution 11:351.

Noss, R.F. 1996. Conservation or convenience? Conservation Biology 10:921-922.

Noss, R.F. 1997. Foreword. Pages iii-iv in T.N. Kaye, A. Liston, R.M. Love, D.L. Luoma, R.J. Meinke, and M.V. Wilson, eds. Conservation and Management of Native Plants and Fungi: Proceedings of an Oregon Conference on the Conservation and Management of Native Vascular Plants, Bryophytes, and Fungi. Native Plant Society of Oregon, Corvallis, OR.

Noss, R.F. 1997. Reinterpreting sustainability: Review of Last Stand: Protected Areas and the Defense of Tropical Biodiversity, edited by R. Kramer, C. van Schaik, and J. Johnson. Trends in Ecology and Evolution 12:450-451.

Noss, R.F. 1997. The failure of universities to produce conservation biologists. Conservation Biology 11: 1267-1269.

Noss, R.F. 1998. Does conservation biology need natural history? Wild Earth 8(3):10-14.

Soulé, M., and R. Noss. 1998. Rewilding and biodiversity: complementary goals for continental conservation. Wild Earth 8(3):18-28.

Miller, B., R. Reading, J. Strittholt, C. Carroll, R. Noss, M. Soulé, O. Sanchez, J. Terborgh, D. Brightsmith, T. Cheeseman, and D. Foreman. 1998/99. Using focal species in the design of nature reserve networks. Wild Earth 8(4):81-92.

Noss, R.F. 1999. The President's Column: Dreams of a millennial president. Society for Conservation Biology Newsletter 6(3):1, 7.

Noss, R. 1999/2000. A reserve design for the Klamath-Siskiyou ecoregion. Wild Earth 9(4):71-76.

Noss, R.F. 1999/2000. The warrior naturalists. Defenders 75(1):21.

Noss, R.F. 2000. Three ways to heal the West. Sierra.March/April 2000:59.

Noss, R.F. 2000. Science on the bridge. Conservation Biology 14:333-335.

Noss, R.F., and P.B. Beier. 2000. Arguing over little things: A reply to Haddad et al. Conservation Biology 14: 1546-1548.

Noss, R.F. 2001. Review of Carnivores in Ecosystems: The Yellowstone Experience (Clark et al., eds.) . Conservation Biology 15:293-294.

Noss, R.F. 2001. Toward a pro-life politics. 2001. Conservation Biology 15:827-828.

Noss, R.F., and R. Kranz. 2001. Ecological issues in conservation: introduction. Ecological Applications 11:945-946.

Noss, R.F. 2001. Review of Forest Fragmentation in the Southern Rocky Mountains (Knight et al., eds.). Landscape Ecology 16:371-372.

Noss, R., and M. Hunter. 2001. From assemblage to community. Conservation Biology 15:1201-1202.

Noss, R.F. 2001. Review of The Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems (Egan and Howell, eds.). Ecological Restoration 19:273-274.

Noss, R.F. 2001. Review of Precious Heritage: The Status of Biodiversity in the United States (Stein et al., eds.). Restoration Ecology 9:476-477.

Miller, B., B. Dugelby, D. Foreman, C. Martinez del Rio, R. Noss, M. Phillips, R. Reading, M.E. Soulé, J. Terborgh, and L. Willcox. 2001. The importance of large carnivores to healthy ecosystems. Endangered Species Update 18:202-210.

Noss, R.F. 2001/2002. Citizen scientist or amateur naturalist? Wild Earth 11(3/4):14-17.

Noss, R.F. 2002. Context matters: Considerations for large-scale conservation. Conservation in Practice 3(3):10-19.

Noss, R.F. 2003. Another dead diamondback. Wild Earth 13: xx-xx.

EXHIBIT 11

Fredrickson, L.H. and Laubhan, M.K., Land Use Impacts and Habitat Preservation in the Grasslands of Western Merced County, California (February 1995)

LAND USE IMPACTS AND HABITAT PRESERVATION IN THE GRASSLANDS OF WESTERN MERCED COUNTY, CALIFORNIA

Prepared for:

GRASSLAND WATER DISTRICT

Prepared by:

LEIGH H. FREDRICKSON
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February 1995

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The Grasslands in western Merced County were once part of an extensive, pristine wetland system that covered at least 4 million acres in the Central Valley of California. At that time the landscape was teeming with abundant wildlife. Large herbivores were common and wetland birds were so numerous that they blackened the skies. Beginning over 150 years ago, the onset of grazing and then farming gradually changed the landscape. Native perennial plant communities were replaced by exotic annuals before 1850, and large predators and grazing animals disappeared. As early settlers discovered the rich soils on the valley floor, development of a huge agricultural industry began. Key to the success of agriculture was an irrigation system to supply water for crop production coupled with an effective system for draining the irrigation water from fields.

As the landscape changed from a pristine setting to an agricultural system, native ecosystems were fragmented and the size of the remaining natural habitats gradually decreased. Conversion of the native systems to agricultural production accounted for much of the loss in size, but establishment of transportation and irrigation systems further fragmented the environment and disrupted migration corridors and movements of animals among remnant habitats. These same corridors allowed the rapid dispersal of exotic plants. Effective use of irrigation waters required land leveling and drainage systems to prevent salt concentration. These modifications further impacted the already greatly modified hydrology associated with the establishment of water storage and distribution facilities. Other changes associated with agriculture further impacted the quality and function of natural environments. The use of pesticides, herbicides and fertilizers degraded water quality. Intensive soil manipulations increased sedimentation, and irrigation water moving through some soils concentrated elements such as selenium that disrupted biological processes.

Because changes associated with agriculture had a profound effect on the size. distribution and quality of remnant natural habitats. many practices and habitats associated with agriculture become important for some wildlife. Grazing lands were used extensively by geese, cranes, and some shorebirds. Waste grains such as corn, wheat, barley and rice provided important sources of high energy foods readily consumed and digested by waterfowl and other granivorous birds. Nesting birds made use of agricultural fields such as alfalfa and wheat before harvest. Sites considered as waste areas by the agricultural community also were important for some wildlife. Sump areas for drain water and drainage ditches sometimes had borders of wetland vegetation that supported diverse wildlife aggregations.

Although the extensive disruption caused by agriculture reduced the numbers and changed the distribution of wild populations, the Central Valley continues to be one of the most important habitats for waterfowl on the North American continent even though habitats now cover less than 300,000 acres. About 60% of the wintering waterfowl in the Pacific Flyway use Central Valley habitats and about 65% of the North American pintail population use these wetland habitats. The largest contiguous block of remaining wetland habitat in the Central Valley is the San Joaquin Valley Grasslands. Of the remaining wetlands in the Central Valley, about 40% are clustered in the Grasslands between Merced and Los Banos along the San Joaquin River. This sizable area is of considerable importance because the variety of habitats are important to the maintenance of biodiversity on a national and international scale. Such habitat diversity is driven by differences in soils and hydrology between the East and West Grasslands. Thus, wetland habitats within the Grasslands represent many different hydrologies ranging from vernal pools to permanently flooded wetlands.

Central Valley habitats increasingly are being impacted by urban expansion. Cheaper land and housing in the Valley compared to the Bay area have attracted many people that are willing to commute long distances for employment. The population of Merced County is expected to grow from 180,000 in 1990 to 260.000 in the year 2000. As this population grows there will be multifaceted impacts that will further degrade both agricultural and remnant natural systems. As urbanization progresses, open space will continually disappear, fragmentation will increase and a host of factors with high potential to disrupt and degrade the functions and values of the Grassland ecosystem will be imminent. Expansion of transportation corridors in number and size will bring more fragmentation and increased air pollution. As areas of impermeable surfaces such as roofs, highways, and parking lots increase, runoff will be more rapid and of greater volume. Stormwater carries sediments and pollutants of many types. Free roaming pets are always in abundance near urbanized areas; their activities disrupt wildlife life history strategies and can result in direct mortality to wildlife. The juxtaposition of urban areas adjacent to natural environments has an insidious impact that gradually reduces the quality and functional area of these habitats. Such changes have been common place across the United States. The decrease in open space and associated fragmentation in conjunction with the effects of transportation, recreation, reduction in air and water quality, and general disturbance gradually modifies plant and animal communities. Monotypic plant communities will be more common. Exotic plant and animal species may increase while native populations disappear.

The Grassland ecosystem is a significant remnant of our natural heritage. Not only is this a unique parcel of a diminishing resource in the Central Valley and the state of California, but these wetland habitats are critical to the survival of migratory species that move across the North American continent and among continents during their annual cycle. Thus, further loss and degradation of this largest remnant wetland habitat in the Central Valley not only will have an important negative impact on local resident wildlife and plant communities, but also will negatively impact migrant animals that move to distant countries during their annual travels. For this reason, protection and appropriate management of this unique ecosystem is essential to assure preservation and to maintain productivity of this important natural heritage. Preservation of this system requires that fragmentation must stop and the area not decrease in size. Some agricultural land use practices will continue to provide important open space as well as important foods or habitats for wildlife. Protection of these agricultural lands from conversion to other uses should be an integral part of strategies aimed at protection of this important system.

Changes in land use require management to emulate historic water regimes that are tied to wetland productivity and life cycle events of wetland wildlife. Careful and timely manipulation of soil and water assure productivity and the biodiversity associated with diverse wetland systems.

This land use study has identified the perturbations that have effected this wetland ecosystem for the past 200 years. Available information clearly demonstrates the importance of strengthening the protection of the Grassland Wildlife Management Area to assure the long-term integrity of this important and unique habitat. Adequate open space must continue to exist in the future as part of protective measures that are essential to maintain the functions and values of this system for wildlife and humans. Additional information and a better understanding of interactions among perturbations must be generated before additional encroachments compromise the viability of this system forever.

INTRODUCTION

Man's first impact in the San Joaquin Valley dates back about 10,000 years to the arrival of immigrants that crossed the land bridge from Asia. At this time California had a rich fauna of wildlife that exploited diverse habitats in the mountains and valleys. The geomorphology of the Central Valley floor had a profound influence on the location, general topography, structure and function of these diverse habitats. The distribution, diversity, and abundance of plants and animals reflected the size and distribution of different habitats. The distribution of habitats in turn influenced the location of Native American populations. The extent Native Americans impacted wildlife populations is not fully known, but many suspect that their hunting skills were adequate to influence the distribution and size of large mammal populations (Burney 1993). However, native Americans differed from subsequent settlers because their way of life had little impact on the landforms or hydrologic regimes that controlled the dynamics of wetland habitats within the San Joaquin River floodplain.

When the Spanish arrived in the San Joaquin Valley in the 1700's, a wonderfully diverse and largely untouched ecosystem composed of interspersed wetland and upland habitats existed between the Coast Range and the Sierra Nevada. As an increasing number of settlers reached California in the 1800's, the potential for agriculture in the Valley was recognized and the first steps were taken to divert water for agricultural purposes.

Agricultural development reached a peak by the middle of the twentieth century. The modifications required for successful agriculture in this semiarid region had a dramatic influence on the landscape. Foremost among these changes were developments required to ensure a more consistent water supply across large portions of the Valley. Reservoirs were constructed to store water and extensive canal systems were built to transport water to farms. Such developments drastically affected the hydrology and water quality within the Valley. In addition, a transportation infrastructure that interconnected farms and communities was required to move equipment. supplies, and commodities, which further altered ecosystem function. As human populations continued to grow, more perturbations impacted an increasingly fragmented landscape. Open space decreased as the demands for housing, recreation, waste water treatment and other essential developments associated with urban and industrial expansion required more land. Continued growth and shifts in the human population in California remain an important influence on current land use. Projections for population growth within the Central Valley suggest a huge increase as more and more people seek affordable land and housing. These demands for living space and associated developments will continue to change the character of Merced County.

Collectively, these factors have had a profound influence on the size, distribution and function of pristine habitats that once provided wildlife populations with the seasonal necessities required for survival and reproduction. Some impacts are subtle and difficult to quantify (e.g., minor disruptions in landform) whereas others, such as changes in land use practices, have obvious results. This report documents the changes in land use in Western Merced County extending back more than 200 years. The implications of these impacts are described in relation to the location and types of activities associated with land use in the County and the potential or documented consequences to natural resource elements. The focus of the study identifies factors associated with the most recent changes in land use related to urban expansion, which will continue to occur in the Central Valley and specifically in western Merced County. The purpose of this document is not to promote the ideology that natural resource concerns be considered and preserved at the expense of economic growth and community development. Such a concept is no longer a viable option in today's society. Rather, the intent is to provide a factual basis that identifies the importance of the Grasslands as an integral component of a much larger landscape that is in imminent danger of being fragmented and disrupted to a greater extent. Further, it is imperative that all individuals and organizations be aware that irreparable damage to the land base likely will have devastating consequences to human populations. Thus, strategies must be implemented to assure that the value and function of natural systems remain viable in order to provide societal benefits and to protect open space for future generations to enjoy.

The focus of this report is on the land-use impacts within an area described as the Grassland Wildlife Management Area and surrounding lands within two miles of the management boundary (Fig. 1). This area, which encompasses 179,463 acres (Merced Data Special Services, Inc. 1993), includes the largest contiguous block of wetlands remaining in the Central Valley of California. A major wintering ground for migratory waterfowl and shorebirds of the Pacific Flyway, the Grasslands also provide habitat for a number of threatened and endangered species. The U.S. Fish and Wildlife Service recognizes the Central Valley (U.S. Fish and Wildlife Service 1986) as one of the most important wintering areas for waterfowl in the nation and the Western Hemisphere Shorebird Reserve Network has designated the Grasslands as an international reserve for migrant and wintering shorebirds. These important wetlands are the remnants of a wetland complex that historically extended throughout the Central Valley and composed part of a 4 million acre wetland system (U.S. Fish and Wildlife Service

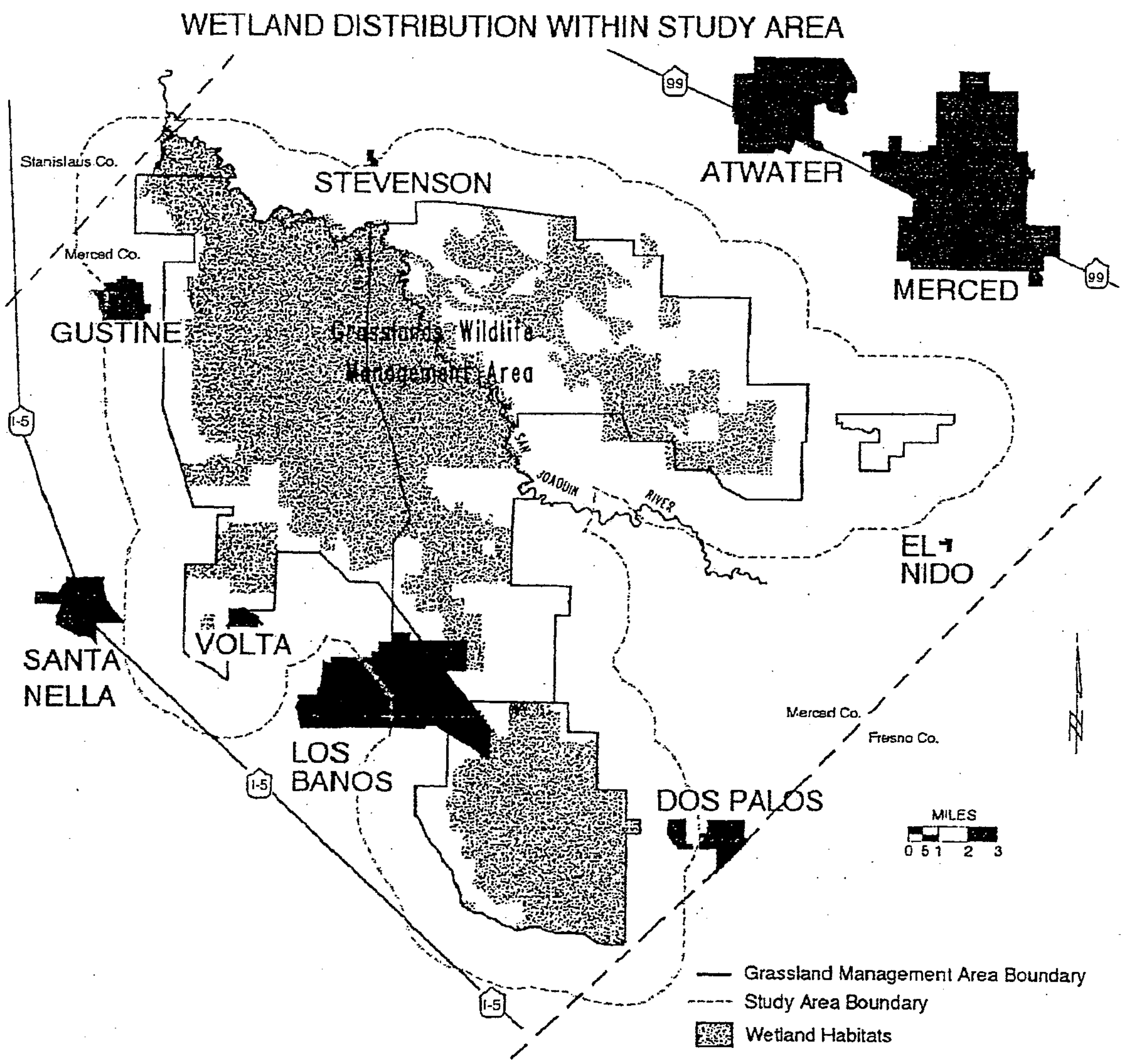

Fig. 1. Grasslands Study Area including a 2-mile perimeter surrounding the Grasslands Wildlife Management Area.

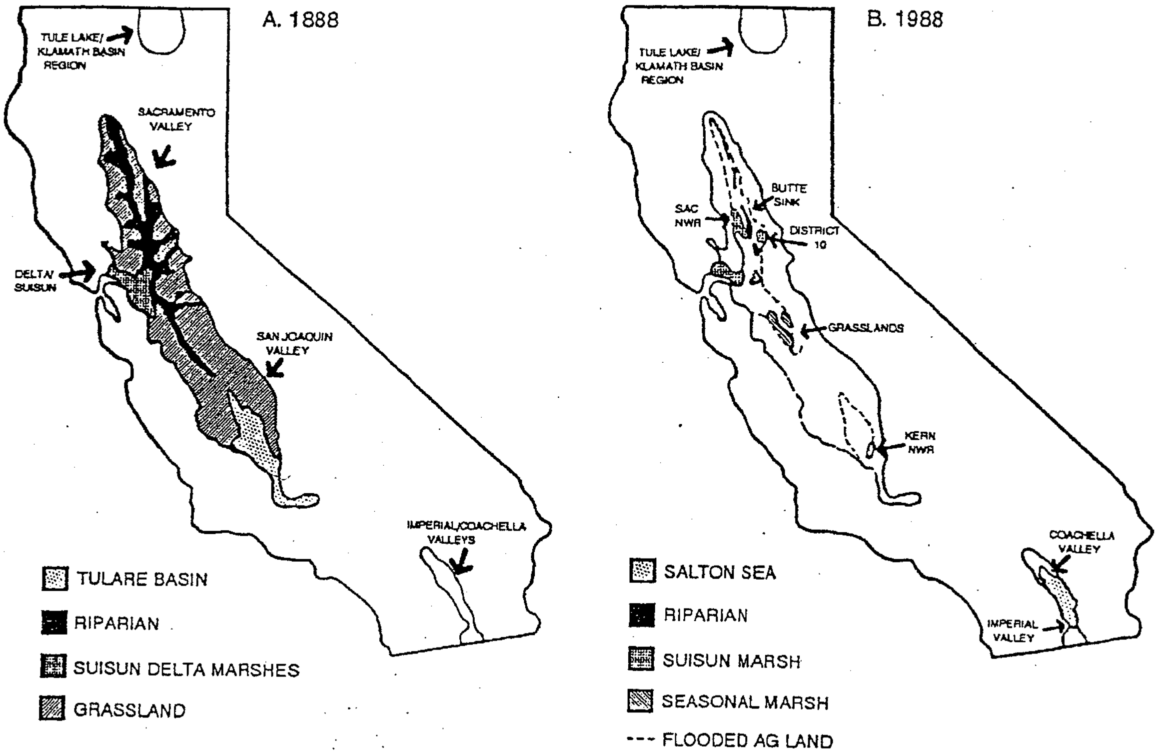

Fig. 2. Location and distribution of general habitat types in the Central Valley of California in 1888 (A) and the fragmentation of these contiguous habitats by 1988 (B).

1978, Fig. 2). Currently, only about 281,000 acres of wetland habitat remain in the entire Central Valley (U.S. Fish and Wildlife Service 1987). Land ownership within the Grassland study area is varied, consisting of federal, state, and private entities (Fig. 3). Habitat types also are diverse, including semipermanent and seasonal wetlands, vernal pools, riparian corridors, native grasslands, and developed agricultural lands. Published reports provide variable estimates of wetland habitats. Merced Special Services, Inc. 1993 provided an estimate of 116,509 acres of wetland habitat in the study area. Other estimates including those from the San Joaquin Valley Drainage Program include areas of seasonal and permanent wetlands. These estimates sum to 91,465 acres but do not include the habitats in the East Grasslands. (Table 1). Earlier reports (Table 1) suggest that over 90% of wetland habitats exhibit seasonal hydrology. This complex of wetland habitats is of special significance because the size, juxtaposition, and connectivity of the different wetland types provide a unique opportunity to sustain native migratory and resident wildlife populations. The associated uplands surrounding the semi-permanent wetlands also are of special importance because they provide nesting

Table 1. Estimated area of wetland habitat (San Joaquin Valley Drainage Program 1990) within the Grasslands Study Area.

	Wetland type	Acre
Grassland Water District	Seasonal	32,000
	Permanent	6,400
	Total	38,400
San Luis National Wildlife Refuge	Seasonal	2,665
	Permanent	40
	Total	2,705
Merced National Wildlife Refuge	Seasonal	725
	Permanent	21
	Total	746
Volta Wildlife Area	Seasonal	2,400
	Permanent	300
	Total	2,700
Los Banos Wildlife Area	Seasonal	3,060
	Permanent	760
	Total	3,820
Duck Clubs outside Grassland Water District	Seasonal	11,144
	Permanent	0
	Total	11,144
TOTAL	Seasonal	83,944
	Permanent	7,521
	Total	91,465

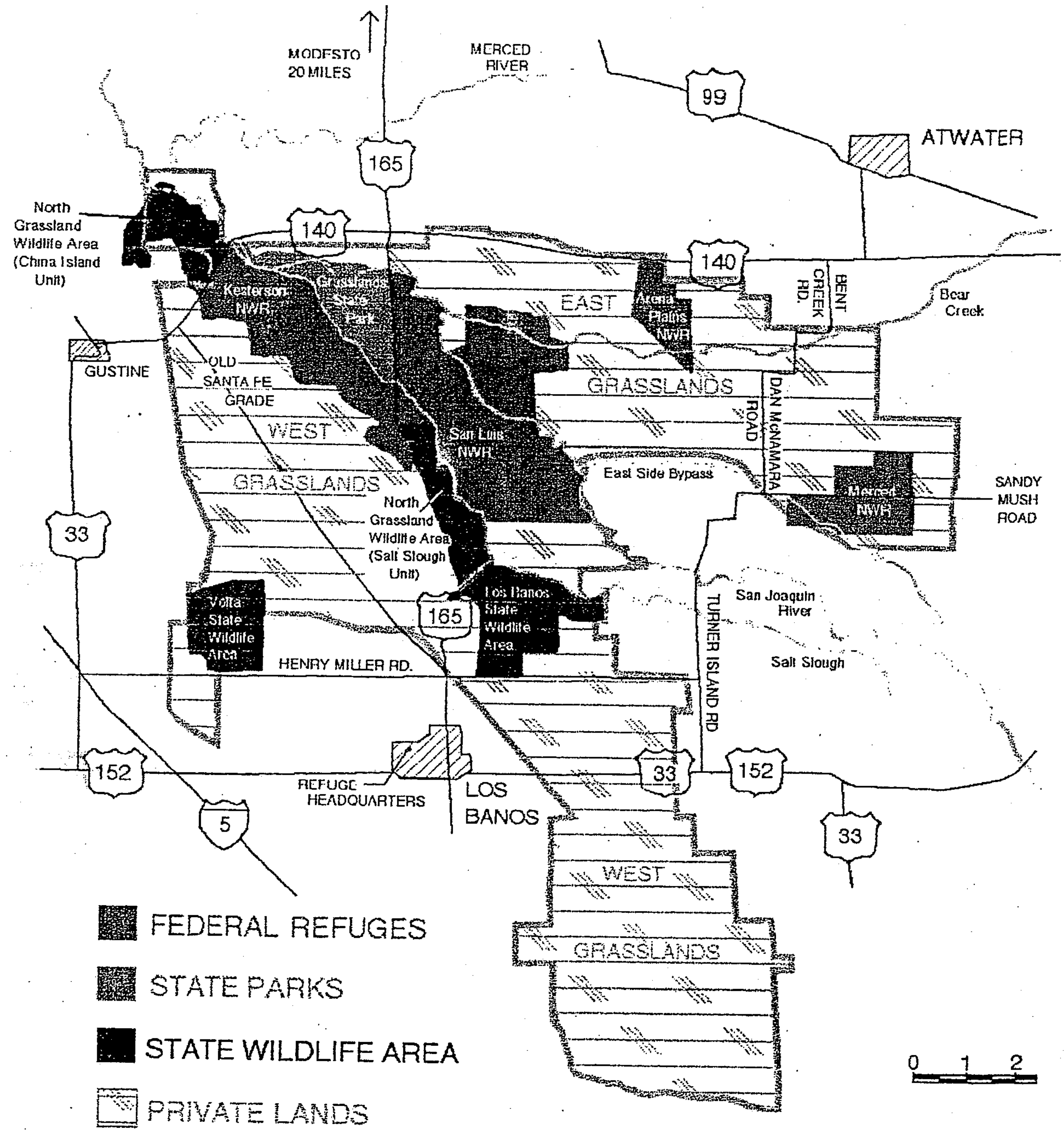

Fig. 3. Federal, State and private owned lands in the Grasslands area.

areas for waterbirds, important food sources for grazers such as geese, and essential habitat for endangered species as well as numerous upland wildlife.

The Grasslands are bounded by numerous towns and cities (Fig. 1). The largest population centers are Merced to the east and Los Banos to the west, with 1990 populations of 50,000 and 13,500, respectively. Smaller communities include Volta, Santa Nella, and Gustine to the west, Stevinson to the north, and El Nido, Dos Palos and South Dos Palos to the east. The 1990

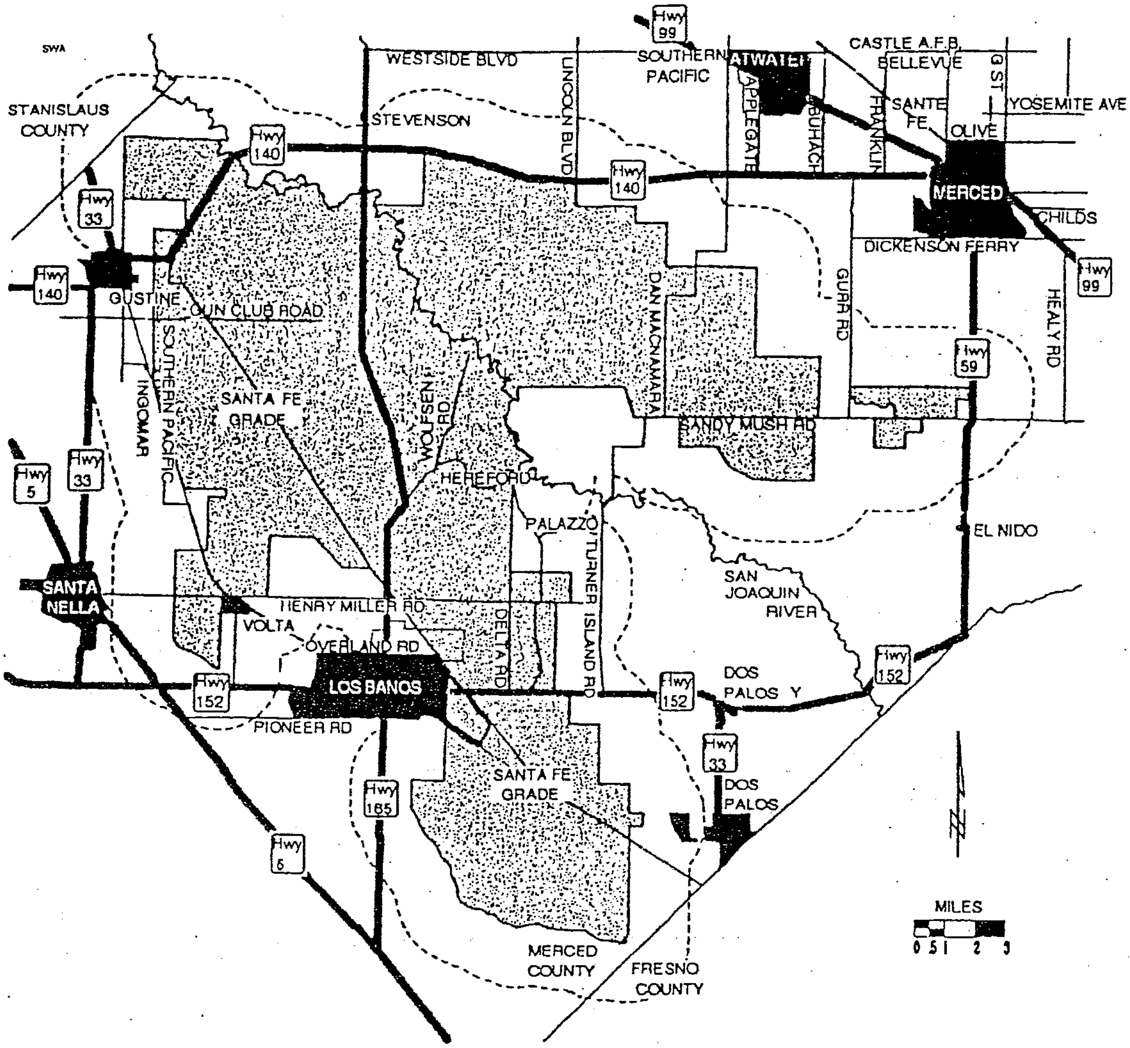

Fig. 4. The location of major roads and highways within the Grassland Study Area of western Merced County.

population of Merced County was 178,403 (Wright 1993) with a projected growth to 264,000 by 2005 (Association of Bay Area Governments 1991). Population projections by the Department of Finance suggest that Merced County will have a population of 626,900 by 2040 (State of California 1993).

Other important features in relation to land use are roads and highways (Fig. 4). Four-lane highways are Interstate 5 to the west, California 99 to the east, and California 152 that runs through Los Banos and bisects the Grasslands into areas described as the North and South Grasslands. Other major state highways impacting the study area include California 140 to the north, California 165 that bisects the area north of Los Banos, and California 33 to the west. Other transportation corridors such as Henry Miller Road also support a considerable amount of local traffic within the study area.

Developments for water transport are key components that influence habitat type, hydrology, and land use in the Grasslands. The area is laced with canals that transport irrigation water or collect irrigation drain water. Starting at I-5 and moving east, the primary water conveyance systems within the study area include the California Aqueduct, Delta-Mendota Canal, Outside Canal, Main Canal, San Luis Canal, San Juan Canal and Eastside Bypass (Fig. 5). There are a large number of smaller canals that move water within and adjacent to the study

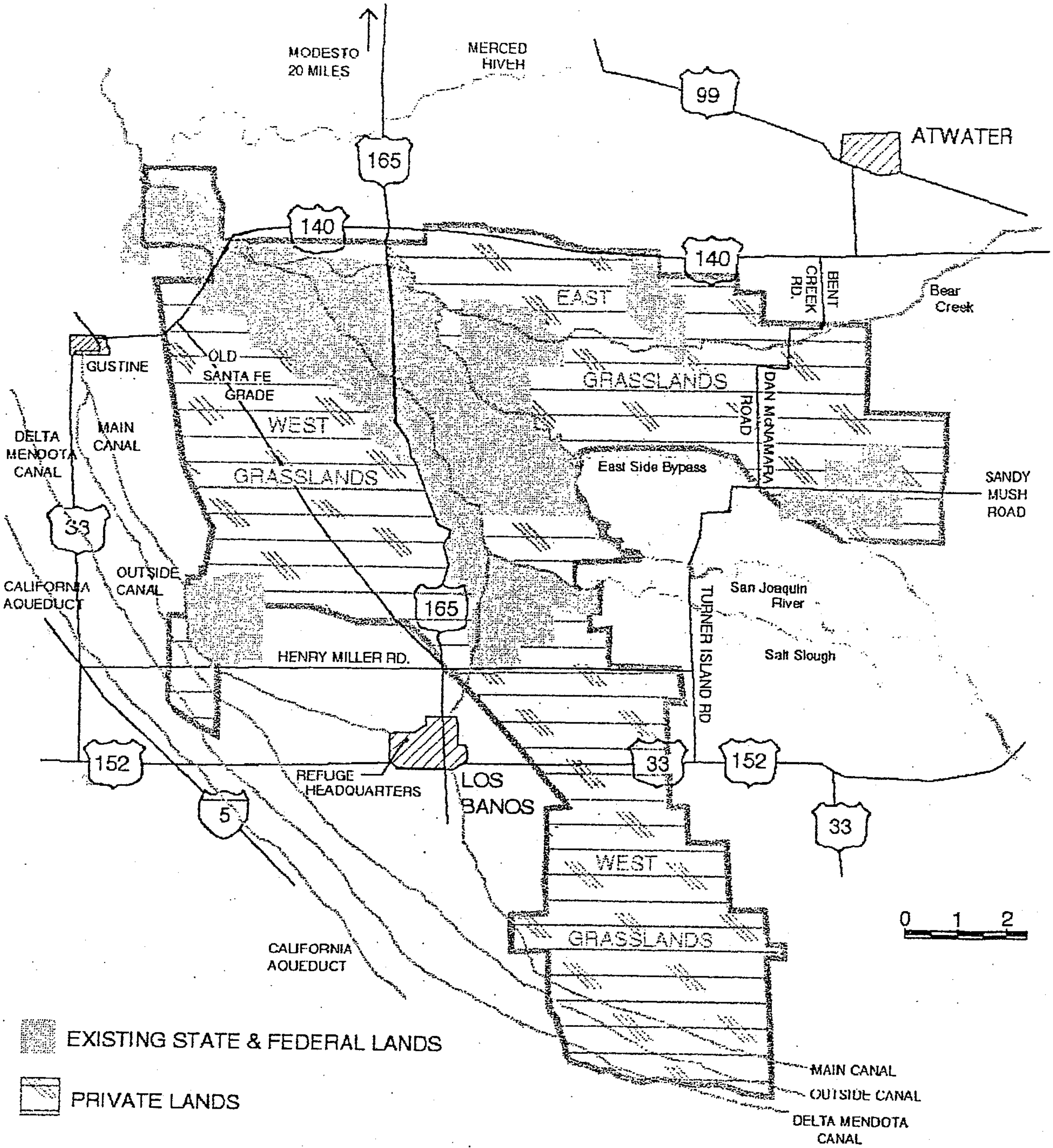

Fig. 5. Location of major water conveyance components effecting the Grasslands Wildlife Management Area.

area (Figs. 6 A and B). In addition, two natural drainages (Mud Slough and Salt Slough) also are used to transport water. These canals have an important influence on the hydrology of the area and, especially for some terrestrial species, represent obstacles for movement.

CLIMATE

The climate of the study area is described as Mediterranean. Distinctly semiarid, the high mountains that enclose the Valley to the east, west, and south, buffer the area from oceanic and continental influences (U.S. Department of

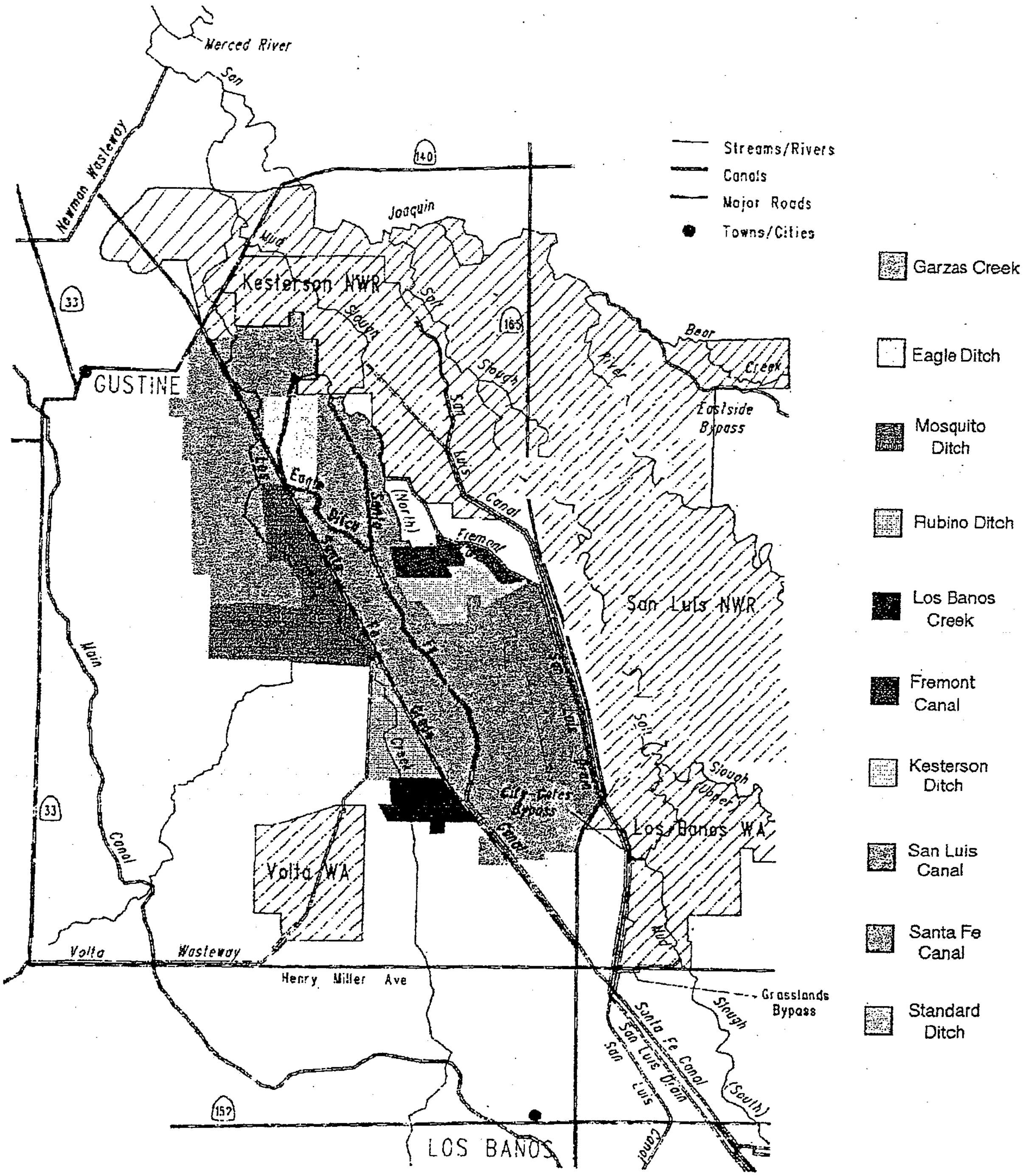

Fig. 6A. Location of water transport canals within the North Grasslands and the areas they supply.

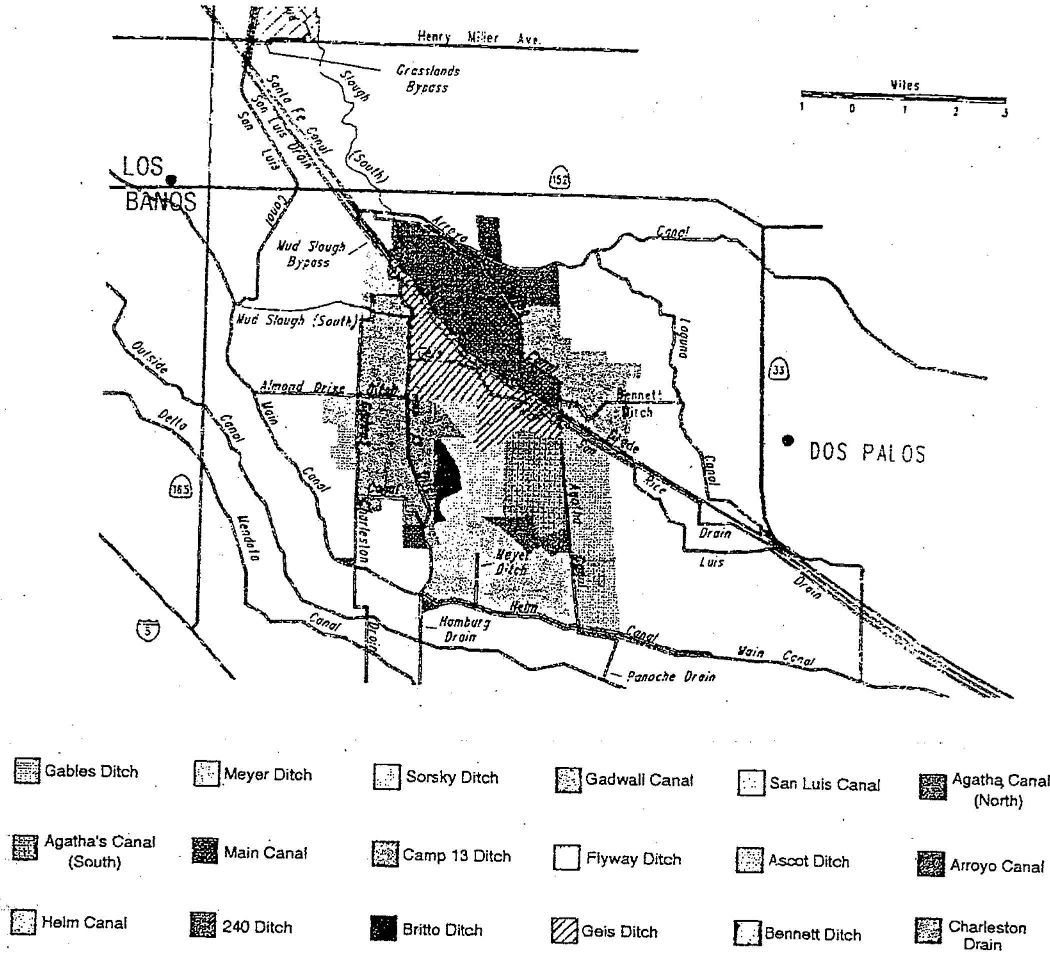

Fig. 6B. Location of water transport canals in the South Grasslands and the areas they supply.

Agriculture 1941, Association of Bay Governments 1991). Summers are long, dry and hot with low relative humidity. During some years the summers are extremely hot. For example, midday temperatures can range from 100 to 110° F, with peaks of 117° F recorded (Nazar 1990). The hottest months are July and August, but clear skies and dry air allow rapid radiation. Thus, night temperatures are frequently 40° F cooler than during the day. This daily variation results in an average summer temperature of only 79° F. Prevailing winds are from the northwest; March is the windiest month. The number of frost free days varies within the study area, ranging from 260 to about 320 days (Nazar 1990).

In contrast, winters are cool and periods of gentle rain, ground fog, and clear frosty weather are common. Winter temperatures average 47.5° F from December through February and the relative humidity is high. Damp, foggy days are interspersed with mild, clear, sunny periods.

Average annual rainfall varies from 8 to 11 inches, depending on location within the study area. However, annual rainfall patterns are erratic and yearly variations of 3 to 24 inches are not uncommon. The rainy period extends from November through April; January is the month of maximum rainfall. Some showers occur in May and in the latter part of September, but little rain falls from June through mid-September.

GEOLOGY OF THE REGION

The current topography and soils in the Central Valley result from processes that began about 150 million years ago when the site was covered by a shallow sea. The North American Plate began to move westward at a faster rate and collided with the diving Pacific Plate. Surface material on the ocean floor was scraped off onto the leading edge of the North American Plate, then folded and pushed upward, possibly as high as 15,000 feet to form what would become the Sierra Nevada mountain range (Whitney 1979). The enormous heat and pressure of these processes changed the sedimentary rock to metamorphic rock present in the Sierra Nevada today. Magma formed along the diving plate and either erupted from onshore volcanoes or cooled within the earth. These processes formed the granitic core of the pre-Sierra Nevada. Activity subsided in the region as the North American Continent pushed the Pacific Plate boundary further westward. The pre-Sierra Nevada mountains then went through an erosional phase in which they were reduced to a gently rolling topography. The granitic core, as well as portions of the metamorphic formations, was exposed on the surface (Ogden 1988). The current Valley floor was originally the site of deposition for chemical precipitates and clastic materials from the ocean. This depositional phase was followed by a downwarping of the ocean floor. Subsequently, thousands of feet of sands, gravel and volcanic materials were deposited in the structural trough that is now the Central Valley floor.

Different geologic processes at different locations in the Valley largely determine present day topographic and soil characteristics. On the west side of the Valley, marine shales were deposited. The Coast Range sediments formed when these deposits were uplifted. The erosion from this uplift created landforms such as the Panoche Pan. Materials from these marine deposits contributed salts, selenium and other potentially toxic substances to the Valley Floor (U.S. Department of the Interior and California Resources Agency 1990).

The dominant landform on the east side of the Valley is the Sierra Nevada Mountains. The eroded material from these mountains is much different from the Coast Range because of the supply of metamorphic and granitic materials throughout the Sierra Nevada. On the east side of the San Joaquin River about 85 percent of the parent material in the Merced area is alluvial material washed from the Sierra Nevada (Arkley 1990). The alluvium varies considerably in mineral composition and in manner of deposition. Some are fresh, unweathered deposits whereas other soils have been developing for thousands of years. Fine silt and clay are dominant in the lower basin area and some soils are strongly alkaline.

SOILS

Soils in the West Grasslands, including the basin, on the basin rim, and on alluvial fans consist of the following: Ediminster-Dospalos-Kesterson nearest the river in the northern part of the Grasslands, Bolfar-Dospalos-Alros along the river to the south, Triangle-Turlock-Britto at the next highest elevation along the river, and finally a bit farther from the river are Pedcat-Marcuse-Volta soils. (Nazar 1990, Fig. 7). Soils on alluvial fans of the San Joaquin Valley are Dosamigos-Deldota-Chateau, and Woo-Stanislaus, but only small areas of these soil types occur within the study area. All of these soils are very poorly drained or poorly drained except for the Woo-Stanislaus soils (Table 2).

Soils in the east Grasslands are very different from those in the west Grasslands largely because of differences in parent material (Fig. 8). These soils fall into two distinct groups and include soils of alluvial fans and floodplains (Merced-Temple-Columbia immediately adjacent to the river and Hilmar-Delhi-Dello along Highway 140 in the north). Poorly drained soils of the saline-alkali basin are Rossi-Waukena, Lewis-Landlow-Burchell, and Fresno-Traver (Fig 8).

HYDROLOGY

Historically the hydrology of wetlands associated with the Grasslands of western Merced County was dynamic, being driven by local and regional precipitation fluxes (Ogden 1988, San Joaquin Valley Drainage Program 1990). Local precipitation occurred as rainfall, which directly influenced wetland hydrology. In contrast, regional precipitation patterns primarily were determined by precipitation events in the surrounding mountains. Melt waters from snow in the Sierra Nevada were particularly important. Regional precipitation patterns influenced the hydrology of the San Joaquin River and its tributaries, which in turn influenced the hydrology in the floodplain by surface flooding or regulation of the water table (Ogden 1988). Thus, both local and regional precipitation patterns interacted to determine the timing, depth, and duration of seasonal flooding that created

Table 2. General characteristics of Grassland soils.

Soil	Location	Description
WEST GRASSLAND SOILS		
Edminster-Dospalos-Kesterson	West of and immediately adjacent to San Joaquin River; In the valley basin	Very deep, nearly level, poorly drained soils that have hummocky microrelief
Bolfor-Dospalos-Alros	West of and immmediately adjacent to San Joaquin River in the valley basin	Very deep, nearly level, very poorly drained soils
Triangle-Turlock-Britto	High zones along west side of San Joaquin River in the valley basin or on the valley basin rim	Very deep, nearly level, very poorly drained soils
Pedcat-Marcuse-Volta	Higher zones away from the west side of the San Joaquin River alluvial rim fans and the valley basin	Deep and very deep, nearly level, poorly drained soils
Dosamigos-Deldota-Chateau	On higher zones away from the west side of the San Joaquin River on low alluvial fans	Very deep, nearly level, poorly drained and somewhat poorly drained soils that are partially drained.
Woo-Stanislaus	On higher zones away from the west side of the San Joaquin River in alluvial fans	Very deep, nearly level, well drained soils
EAST GRASSLAND SOILS		
Merced-Temple-Columbia	Immediately adjacent to east side of San Joaquin River on alluvial fans and floodplains, including natural river levees	Parent material is primarily granitic, water table is near surface; Historically these soils frequently were flooded in early summer for extended periods; Poorly drained
Hilmar-Delhi-Dello	Along Highway 140 east of San Joaquin River on alluvial fans and floodplains	Parent material is granitic alluvial; modified by wind and water level to undulating topography; Permeable to poorly drained
Rossi-Waukena	To East of San Joaquin on higher ground in poorly drained saline-alkali basins	Nearly level soils just above flood level; Parent material is primarily granitic; Poorly drained
Lewis-Landlow-Burchell	East of San Joaquin River on higher ground in poorly drained saline-alkali basin	Parent material is igneous rock nearly level with poor drainage
Fresno-Traver	East of San Joaquin River on higher ground in poorly drained saline-alkali basins	Parent material is granitic; generally level with mounds; Poorly drained

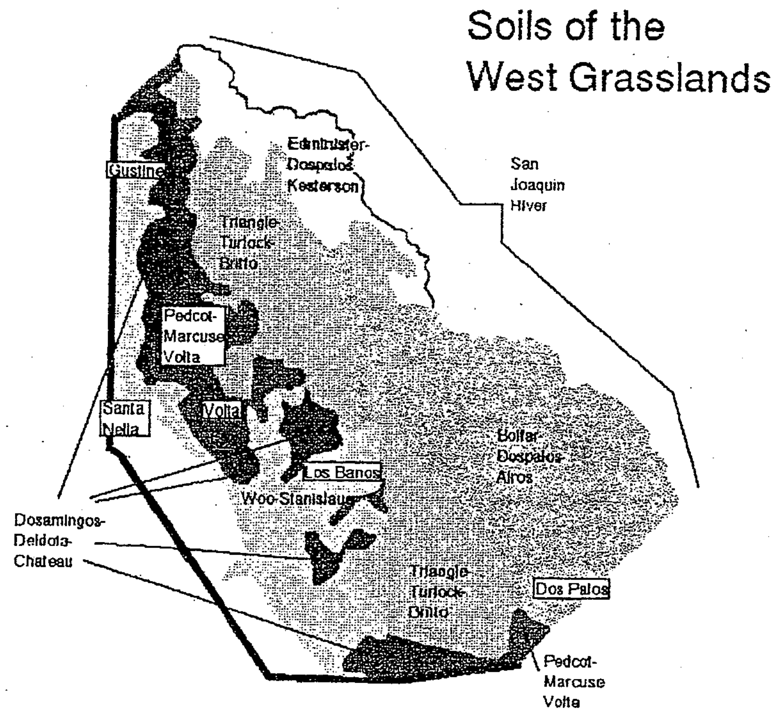

Fig. 7. Soils of the Grassland Study Area, west of the San Joaquin River.

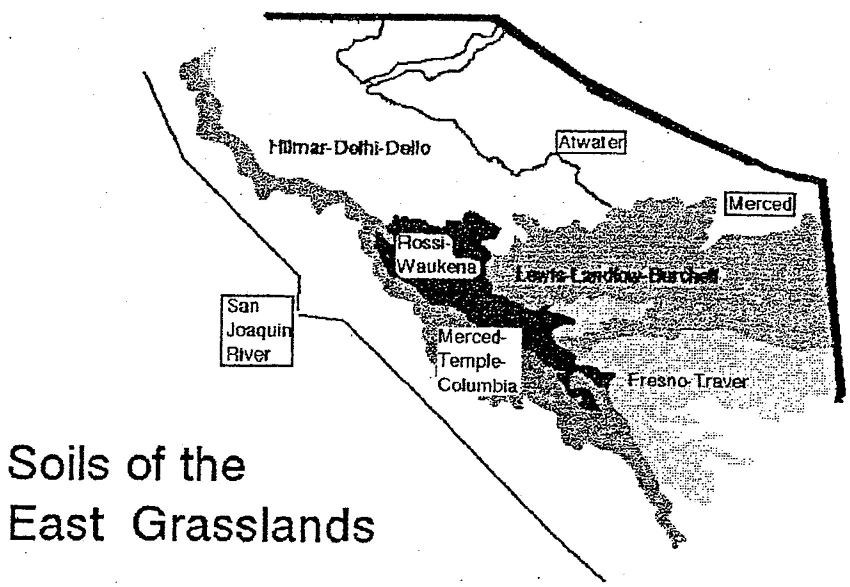

Fig. 8. Soils of the Grassland Study Area, east of the San Joaquin River.

and nourished wetland habitats and provided a haven for myriad wildlife species. Some of the most extensive flooding in the San Joaquin River system occurred when high flows into the Tulare Basin reached levels that caused water to flow northward from this closed basin (Ogden 1988). The natural ridge along the Kings River is at an elevation of 210 ft. msl. Thus, water flows northward when surface water increases above this elevation. Such high flows were recorded in 1862 when Tulare Lake was at 220 ft. msl and likely covered over 500,000 acres with depths up to 40 feet. The normal pattern of precipitation is erratic but the rainy season consistently occurs during winter (November to April). January is the wettest month. This precipitation provides the water supply for the extensive area of vernal pools and seasonal wetlands within the study area. Historically, the tule marshes within the floodplain were replenished with water during the high flows normally associated with melt water from the mountains in spring and early summer. These variable patterns of precipitation and melt water created a dynamic wetland complex with great seasonal and among year variation in number of basins flooded, area of wetlands flooded, and amount and types of foods produced (Ogden 1988). The topography and soils, wetland size, wetland depth, and interconnections with sloughs produced a multitude of different wetland habitats that largely have been disrupted by human activities.

Historically, the value of this wetland system to wildlife was enhanced by its direct connection to other important wetland habitats within the Central Valley of California, including the Delta Region of the San Joaquin and Sacramento rivers, the Sacramento Valley to the north, and the Tulare Basin to the south (Fig. 2). Thus, the Grasslands originally were part of a continuum of wetland habitats extending from the northern sections of the Sacramento Valley to the Tulare Basin. This vast complex of habitats provided myriad opportunities for wildlife to meet life history requirements.

Today, the surface hydrology is driven by flows through man-made canals (Figs. 5 and 6). The water supply primarily enters the Grasslands through a complex water distribution infrastructure. During periods of heavy precipitation and high flows in canals, there is some uncontrolled flooding. The remnant wetlands are flooded during the winter but some areas are flooded in fall to attract early migrant waterbirds. This consistent pattern of early fall flooding of some habitats differs from the historic hydrology of natural flooding during the wet winter period.

Little is known about the historic subsurface hydrology. Currently, the subsurface hydrology reflects the impacts related to water projects and water use by agriculture, municipalities and industry. Undoubtedly, the timing and amount of natural flow in streams of all sizes has influenced discharge and recharge and thus, the current ground water levels. Extraction of ground water for various uses further impacts the ground water reserves. The drainage systems associated with agriculture also have an important influence because water must be transported away from the root zone and these drain waters often carry toxic materials that influence the overall quality of ground water.

HISTORY OF THE GRASSLAND WATER DISTRICT

Much of the current land use in the Grasslands can be traced to the vision of Henry Miller who arrived in the San Joaquin Valley in 1864. Miller's dream was of irrigation (Winton 1962). He saw the potential to capture the annual seasonal flows of the San Joaquin River and use these waters during the dry season to improve agricultural opportunities, including the ability to increase forage production for cattle. Miller and Lux formed a company, Miller and Lux, Incorporated, that was to have a profound influence on wetland and grassland habitats in Merced County. Construction of the first irrigation canal began in 1871 and continued until 1878. Evidence of these early developments designed to irrigate semi-arid pastureland is still evident in the Grasslands and mark the beginning of human efforts to divert water from the western slopes of the Sierra Nevada mountains. Gradually waters from the Kern, Little Kern, Tule, Kaweah, Kings, Fresno, and Chowchilla rivers, as well as run-off from the Coast Range, also were captured for agricultural purposes.

Other entrepreneurs, including James Ben-Haggin and Lloyd Tevis also had an important influence on more southern San Joaquin Valley habitats (Winton 1962). These two men established the Kern Land and Cattle Company that encompassed a large land base, including two-thirds control of the water flow in the Kern River. As Miller and Lux expanded their operations to the south, conflicts developed with the Kern Land and Cattle Company. These conflicts lead to the establishment of Buena Vista Lake in the late 1880's.

A dam was built across the San Joaquin River near Mendota to permit diversion of water to the Grassland region in Merced County. Dikes and levees were constructed at strategic points to allow excess irrigation water from Miller and Lux croplands to be used to flood the Grasslands during periods of adequate water availability. When such diversion occurred in summer and fall, this water provided waterfowl with excellent habitats. Excess water for hunting lands also was furnished by Miller and Lux, but the amount depended on water availability in the San Joaquin and Kings rivers. In dry years, no water was furnished. Miller and Lux, Inc. claimed much of the water the Federal Government needed for the development of the Central Valley Project. The legal battle for water was resolved when the law of riparian rights became the water law of the state of California.

In 1926, Miller and Lux liquidated 98,234 acres in the area now known as the Grasslands (Leach 1960). Lands adjacent to the San Joaquin River were sold to cattlemen, dairymen and duck clubs. When the land was sold, Miller and Lux retained title to the water rights appurtenant to those lands, whether riparian, prescriptive, or appropriative. These water rights were essentially the rights to the San Joaquin River flood waters when the flow of the river exceeded the requirements of the croplands served by Miller and Lux. Even though land owners did not have water rights during this time, excess water was made available to land owners to flood wetlands and grazing lands.

By the 1930's the Federal Government took control of the natural resources of the Central Valley and foremost among these resources was water. The U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, along with other state and federal agencies, established control of the water, but use for fish and wildlife was not identified until the Central Valley Project was reauthorized in the 1950's.

In 1939, Miller and Lux sold the water rights to the 98,234 acres serviced by San Joaquin River water. The Federal Government paid $2.45 million for these rights and agreed to protect the water right by continued diversion of the water until the United States was ready to use the water elsewhere in the Central Valley. Provision to store these waters was possible with the construction of Friant Dam on the upper reaches of the San Joaquin River. Friant Dam was completed in 1944, but transfer of this water was not possible until completion of the Delta-Mendota Canal in 1952. Various landowners in the Grasslands realized their water supply was about to be cut off following completion of Friant Dam. This stimulated the organization of several livestock and duck hunter associations. On 2 August 1944, all such associations were merged into the Grassland Water Association and incorporated under state laws as a non-profit mutual water association. The original area serviced by the Grassland Water Association was 61,370 acres. Of this area, 53,747 acres either were controlled or owned by 139 duck clubs or livestock companies. Although the primary incentive of livestock companies was beef production, most of these lands were flooded for waterfowl at some time during the year. The number of clubs or livestock companies has varied over the years, but the majority of the land within the Grassland Water District continues to be wetlands that are flooded seasonally each year.

Some important changes also have occurred in the management of Grassland habitats in the past decade. Originally, grazing was an integral part of duck club operations. Grazing for prolonged periods by domestic stock year after year led to some conflicts between beef production and maintaining high quality wetlands for waterfowl and other waterbirds. A dependable water supply always has been a major concern for wetland managers in the Grasslands. As important is the timing of the supply in relation to wildlife need. Recently, legislation (1992 Central Valley Project Improvement Act) has identified the importance of a reliable water supply for maintaining wetland values in the Grasslands. Deliveries of these waters was initiated in 1993. Since then, additional conflicts have developed over the rights to these waters in response to the 1992 legislation.

RATIONAL FOR PRESENTATION OF THIS REPORT

The history of the Grasslands is complex and well-documented, yet confusing to many who have not taken the opportunity to peruse available information. Such confusion results because much of the information is anecdotal or qualitative, rather than quantitative. Thus, there often are discrepancies among published reports concerning the *exact* timing of specific events that have had great significance in understanding the current status of the Grasslands from a natural resources viewpoint. As a result, it is difficult to synthesize this wealth of knowledge in an enlightening manner. This particularly is true when an attempt is made to integrate historical information regarding the main topics of interest, which include (1) the impact that habitat changes have exerted on wildlife populations, (2) the causes of habitat change, and (3) how future changes in the Grasslands ecosystem may further impact plant and animal communities. Fortunately, however, the *chronology* of events relating to a specific topic are consistent. For example, the chronology of habitat change in the Grasslands are equable among documents although specific dates of important events may not coincide exactly. Therefore, it remains possible to use past information to gain valuable insight concerning potential impacts that may result if the Grasslands continue to be modified. The difficulty resides in attempting to combine information relative to human demographics, land use changes, habitat alteration, and wildlife populations into a format that can be understood by individuals with various professional backgrounds and, more importantly, can be used to arrive at decisions that will protect the existing integrity of the Grasslands.

To solve this dilemma, we have taken an approach whereby information for a specific topic will be presented separately at varying scopes. Thus, the history of habitat loss/change will be presented for the Pacific Flyway and continent, the state of California or the Central Valley, and finally the San Joaquin Valley and Grasslands study area. A similar tact will be used to present information on changes in population levels of species. Organization of the information in this format hopefully will serve to identify the importance of scale when evaluating the value of an area. Benefits often are integrally linked to other areas or ecosystems, thereby forcing considerations of the whole (e.g., Pacific Flyway) rather than component parts (e.g., Grasslands). Additionally, valuable insights can be gained by incorporating information or facts from other sources. Although the Grasslands is unique in many ways, some impacts that currently threaten this area have become a reality in other regions of the country. We would be amiss if such lessons were not taken into account. Subsequently, biological information will be presented to more specifically identify the causal agents involved in ecosystem functions and the importance of temporal and spatial aspects of habitats in determining the reproductive success and survival of wildlife.

LEGISLATION OF IMPORTANCE TO LAND-USE IMPACTS IN THE GRASSLANDS

A large number of legislative actions dating back to the early 1800's have had important implications for land use activities in the Grasslands (Table 3). Among the earlier acts of

Table 3. Selected events in wetland and land-use legislation with implications for grassland habitats.

1802	U. S. Army Corps of Engineers created for military and civilian construction works, including navigation.
1849	Swamp Lands Act passed to allow settlement of swamplands with agreement to clear land.
1862	Homestead Act passed to open up western lands to settlement and development.
1877	Desert Lands Act passed to open southwest for settlement.
1886	Green Act permitted levee construction along natural drains to permit reclamation of federal land in the floodplain
1902	Reclamation Act passed giving authority to the U.S. Bureau of Reclamation to develop water supplies for land reclamation and irrigation.
1903	President Roosevelt designates the first national wildlife refuge at Pelican Island, Florida, as a bird sanctuary.
1936	Flood Control Act passed following an earlier version passed in 1927 giving the Army Corps authority for flood control efforts on major streams and appropriating funds for public flood control works.
1948	Water Pollution Act establishes study program and grants for waste treatment.
1950	Dingell-Johnson Act authorized federal aid for restoration of freshwater fish.
1950	President's Water Resources Policy Commission.
1954	Watershed Protection and Flood Prevention Act establishes technical and financial aid to local organizations for watershed work plans.
1954	Public Law 674. Authorized the use of Central Valley Project Water for Fish and Wildlife purposes.
1964	Wilderness Act authorizes reservation of federal lands as wilderness areas.
1968	Wild and Scenic Rivers authorizes reservation of river reaches for preservation.
1969	National Environmental Policy Act requires federal agencies to prepare environmental impact statements on projects and develop mitigation plans with public participation.
1972	Clean Water Act authorizes the Environmental Protection Agency to create and enforce water quality standards and guidelines for permitting draining and filling of wetlands (administered by the Army Corps).
1973	Endangered Species Act authorizes the Fish and Wildlife Service to list threatened and endangered species, to designate critical habitat areas, and to develop recovery plans.
1977	Executive Order 11990 mandating that all federal agencies work to minimize impacts on wetlands.
1978	Fish and Wildlife Improvement Act. Authorized water to be made available for Grassland Water District on a nonreimbursable basis.
1985	Food Security Act establishes the Wetlands Reserve Program administered by the U.S. Dept. Agriculture's Soil Conservation Service to provide funds to farmers who keep wetlands out of production.
1986	Emergency Wetlands Resources Act
1988	The National Wetlands Policy Forum sets a goal of "no net loss" for wetlands and Presidential candidate George Bush endorses the goal.
1990	Water Resources Development Act passed.
1990	Truckee-Carson Water Rights Settlement Act passed authorizing water-rights acquisitons from a Bureau of Reclamation project for the purposes of restoring the Stillwater National Wildlife Refuge wetlands.
1990	Coastal Wetlands Protection, Planning, and Restoration Act authorizes $35 million for wetlands restoration in coastal Louisiana.
1991	National debate erupts over Vice-President Quayle's attempt to change the definition of wetlands used in the 1989 federal wetlands delineation manual thereby potentially excluding from federal protection 50% of the nation's remaining wetlands.
1992	Central Valley Project Improvement Act sets aside 800,000 acre-feet of water for fish and wildlife protection and an additional 430,000 acre-feet of water specifically for wetland use. Also establishes a Restoration Fund with an initial $35 million.

importance were the establishment of the U.S. Army Corps of Engineers, Desert Lands Act, and Reclamation Act which set the stage for changes in natural ecosystems to an agricultural environment. These acts and others also set in motion major changes that led to the destruction and degradation of wetlands, loss of natural habitats and open space, loss of animal populations and plant communities, and changes in hydrology of the San Joaquin Valley.

As natural systems have been lost and degraded there has been a gradual shift in attitudes and legislation to counter earlier programs that exploited systems without consideration for environmental issues (Table 4). Public concern for ecosystems date back to 1891 with the Forest Resources Act which was stimulated by exploitation of timberlands. Water resources were not identified in Federal legislation until 1964 when the Wild and Scenic Rivers Act was passed. Thereafter coastal areas were protected under the Marine Protection and Sanctuaries Act of 1972. Most recently wetlands have been identified as systems holding high public value and legislation such as the Emergency Wetlands Resources Act of 1986 and Coastal Wetlands Protection, Planning, and Restoration Act of 1990 (which protect Louisiana coastal habitats) have been important. Among the most important acts affecting the San Joaquin Valley, including the Grasslands study area, is the 1992 Central Valley Project Improvement Act which set aside 430,000 acre-feet of water for Central Valley wetlands protection and establishes a Restoration Fund with an initial $35 million. Some ecosystem protection also is apparent in some legislation, including the swamp buster provision of the 1985 Food Security Act (Table 3).

Although the purpose of legislation is to establish standards and guidelines for the protection, regulation, and management of natural resources, the types of legislation approved also reflects public attitudes and perceptions regarding wildlife landscapes. In colonial times, some states established game laws in the 1700's to set seasons that provided some annual protection for game species whether they were fish, birds, or mammals (Table 5). The Lacey Act of 1900 was the first protective federal legislation to protect wild animals. The most all-inclusive legislation that protects ecosystems as well as individual species is the National Biological Diversity Conservation and Environmental Research Act of 1990. The passage of such legislation indicates laypersons are becoming increasingly aware that destruction and modification of landscapes may be potentially deleterious to all living organisms, including humans.

Table 4. Evolution of concern for ecosystems in the United States.

Ecosystem	Act
Timberlands	Forest Resources 1891
Grazing Lands	Taylor Grazing 1934
Wildlife Sanctuaries	Fish and Game Sanctuary 1934
Wilderness	Wilderness 1964
Rivers	Wild and Scenic Rivers 1964
Coastal Areas	Marine Protection and Sanctuaries 1972
Forest Lands	National Forest Management 1976
Rangelands	Federal Land Management and Policy 1976
Wetlands	Emergency Wetlands Resources 1986
	Coastal Wetlands Protection, Planning, and Restoration 1990
All Ecosystems	National Biological Diversity Conservation and Environmental Research 1990

Table 5. Evolution of concern for species groups in the United States.

Species group	Act
Large (Huntable) Mammals	Early State Game Protection
Birds, Fish	Laws (1700's)
Wild Animals	Lacey 1900
Wild Birds	Migratory Bird Treaty 1918
Fish	Fish Restoration and Management 1950
Plants, Animals	Endangered Species 1973
All Species	National Biological Diversity Conservation and Environmental Research 1990

GRASSLAND PLANT COMMUNITIES

The pristine area of western Merced County was part of a grassland and wetland ecosystem sometimes described as California Prairie and Tule Marsh habitats (Fig. 9. Burcham 1957, Munz and Keck 1959). The grassy portion of the region was dominated by perennial grasses that were excellent pasture. Unfortunately, changes in vegetation composition and distribution in the Valley following the arrival of the Spanish in California never were documented (Heady 1988). Nevertheless certain conditions likely occurred and are generally agreed upon by experts. *Stipa pulchra,* a perennial bunchgrass, probably dominated the Valley grassland, particularly at higher elevations that were drier. Interspersed among the bunch grasses were annuals, especially at lower elevations immediately adjacent to wetland habitats in Merced County. The grassland type characteristic of the region occurred on a wide variety of soils with some authors identifying the distribution on as many as 195 soil series (Barry 1972). Broadleafed plants, especially perennials with bulbs, were interspersed among the grasses. Herbaceous annuals were dominated by members of the Caryophyllaceae, Compositae, Cruciferae, Labiatea, Leguminosae, and Umbelliferae (Stebbins 1965).

The seeds of alien species were present in the adobe of the earliest Spanish Missions, providing evidence that the first changes in grassland plant composition in California preceded extensive settlement by Europeans (Hendry 1931). However, the timing and extent of these early changes in plant communities is poorly documented. Undoubtedly, some changes in the grassland community probably preceded the period of intensive grazing that began after the mid-1800's. Records indicate that introduced species such as wild oats (*Avena fatua*) and *Brassica nigra* were abundant before livestock overgrazed the area. Certainly, additional changes in the pristine grassland occurred as more

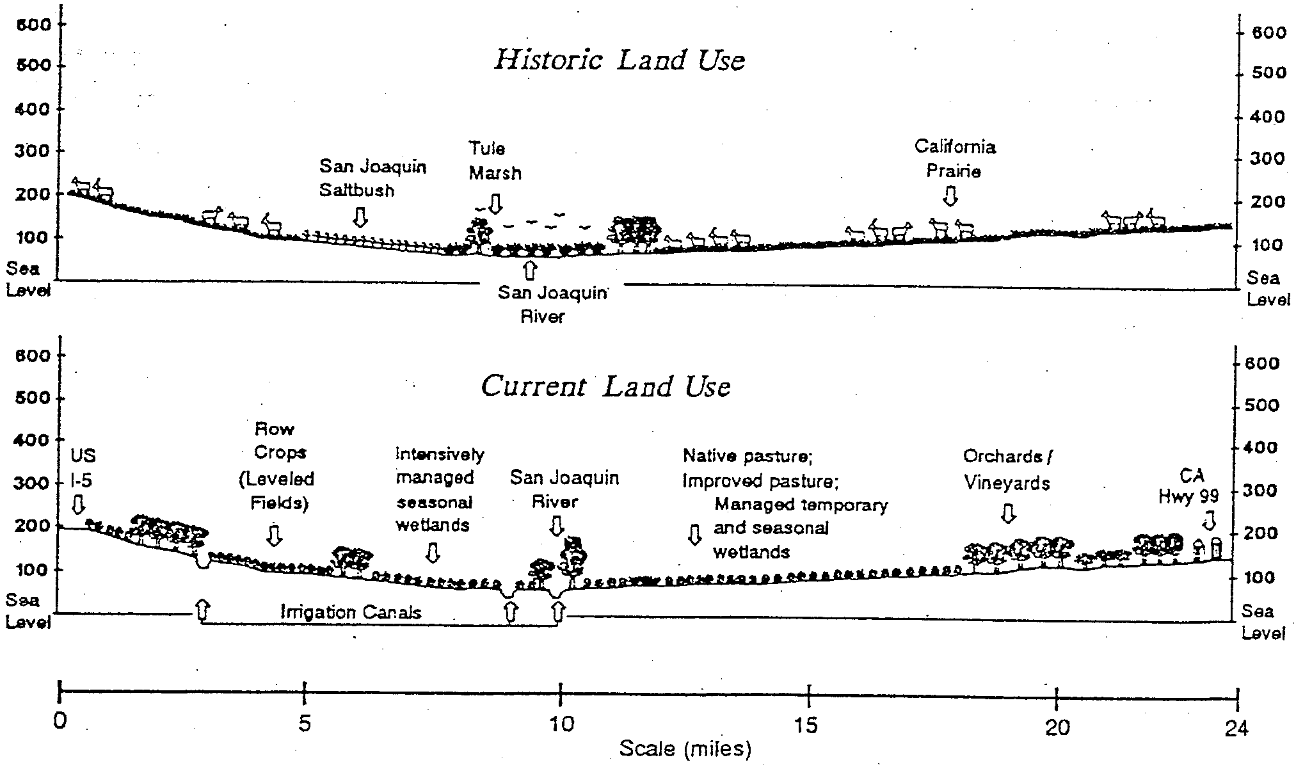

Fig. 9. Comparison of the distribution and type of vegetation communities in the study area before and after agricultural development.

and more settlers arrived in the Valley (Burcham 1957). There is disagreement over the relative importance of how different factors altered the pristine California Prairie (Heady 1988) but at least 4 factors commonly are associated with changes in the prairie community: (1) invasion by alien plant species, (2) changes in the kinds of animals and their grazing patterns, (3) cultivation, and (4) fire, as well as the complicated interactions among these factors (Heady 1988). A major change in the Grasslands was associated with the introduction of domestic livestock. Likewise, the arrival of many alien seeds, bulbs, and cuttings with miners in the 1850's provided another source of plant material that compromised native plant communities. Extensive areas also were converted to dry-land farming with grains and forage as the principal crops (Heady 1988). Those areas that were farmed and have reverted to grassland continue to be dominated by annuals rather than perennials. The role of fire in pristine grasslands is not documented, but fire likely was a part of the evolutionary history of the California Prairie (Heady 1972). Thus, as is the case with any changes in pristine environments, many different factors interacted in combination to result in the demise of the original grassland community in western Merced County.

Historic and current information suggest that the general macroscale distribution of native plant communities has not been influenced by land use changes. Thus, the current distribution of wooded riparian forests, grasslands, marshlands, and shrublands is similar to the distribution during the past several hundred years (Heady 1988). However, the species composition of these communities has changed. The pristine perennial grassland community was dominated by *Stipa pulchra* in association with other perennials including *Aristida hamulosa*, *Elymus glaucus*, *E. triticoides*, *Festuca idahoensis*, *Koeleria cristate*, *Melica californica*, *M. imperfecta*, and *Poa scabrella*. Some annuals were present and included *Aristida oligantha*, *Descampsia danthonioides*, *Festuca megalura*, *F. pacifica*, and *Orcutti* spp. The replacement annual grasslands have a composition that is highly variable (McNaughton 1968), but common species include *Bromis mollis*, *B. rigidus*, *B. rubens*, *Erodium botrys*, *E. cicutarium*, and *Avena fatua*.

WETLAND COMMUNITIES

Status of Continental Wetlands

To understand the importance of Grassland habitats, understanding the status of wetlands on a larger scale is necessary. Nationwide, wetlands have received considerable attention since 1985 because of the North American Waterfowl Management Plan and the 1985 Food Security Act. Although exact estimates of the original acreage of wetlands in the 48 coterminous states were never made, experts suggest there were about 220 millions acres of wetlands in colonial America (Dahl 1990). Wetland loss has been excessive during the past 200 years and today less than 100 million acres remain (Dahl and Johnson 1991). Historically, wetland losses primarily have been associated with conversion of native habitats for agricultural purposes. For example, from the mid-1950's to the mid-1970's, 87% of wetland loss was related to agriculture (Frayer et al. 1983). Although this rate has declined to 54% from the mid-1970's to the mid-1980's, agriculture continues to have an important impact on wetland losses. In contrast, urban land uses accounted for about 5% of wetland losses during the 30-year period beginning in the mid-1950's (Tiner 1984).

The total loss of wetlands has been devastating to wildlife populations and has disrupted many wetland values and functions that subsequently compromise economic benefits to society (Odum 1978). Factors such as fragmentation, changes in hydrology, disruption of functions, excessive losses of ephemeral and temporary wetlands, increased sedimentation, and excessive nutrient or toxic chemical loads all have major impacts on remaining wetland habitats or influence the type and duration of use by wildlife (Table 6). Fragmentation of wetland corridors and wetland systems is a national problem and is well-represented by the current discontinuous distribution of remnant wetlands in California.

Status of California Wetlands

California had an estimated 5 million acres of wetlands in the mid-1800's (California Department of Fish and Game 1983). The majority of these wetlands were in the Central Valley, but other sites such as the Klamath

Table 6. Examples of ecological implications resulting from wetland loss and degradation and modified hydrolgy.

Perturbation	Ecological Implication	
	Habitat	Wildlife
Wetland drainage	Loss of habitat	Populations reduced
Wetland complexes disrupted by highways, farming urganization, etc.	Habitat quality decreases	Fewer species present; Resources for some life cycle events eliminated or reduced
Upstream reservoirs	Changed hydrology results in changes of plant species composition and productivity	Some species eliminated; Resources available for lesser number of animals
Nonpoint Pollution	Sediments and pollutants accumulate in wetlands; Undesirable Plant Monocultures become more common	Certain species and/or age classes are impacted; Food production declines

Basin were of great importance to the waterfowl resource (Heitmeyer et al. 1989). Unfortunately more than 95% of these historic wetlands have been destroyed or modified (Frayer et al. 1989, Gilmer et al. 1982). Remnant wetland habitats primarily are within the Central Valley where about 287,000 acres remain. Few if any of these remnant wetlands remain in pristine condition because man has impacted each wetland directly or indirectly. Changes in volume and flow patterns of water, ground water levels and sedimentation rates are just a few examples of the widespread modifications to wetland resulting from man's activity. Privately owned and operated duck clubs are particularly important because they account for two-thirds, or over 170,000 acres, of these wetland habitats. The remaining one-third is divided between state and federal ownership and managed as wildlife areas. Nearly all of these remnant habitats are managed intensively for the benefit of waterbirds, especially waterfowl (Heitmeyer et al. 1989). Significant portions of the Grasslands are now in state or federal ownership or easements (Fig. 3). Efforts to increase public ownership and easements will continue.

Status of San Joaquin Valley Wetlands

The importance of the Grassland study area is imminently clear because of the size, diversity of wetland types, and juxtaposition of remnant habitats (Table 7). Nevertheless, the Grasslands are a tiny remnant of wetlands that historically served as an important wetland corridor between the Delta and the Tulare Basin. Nevertheless, remnant wetlands in the entire San Joaquin Valley account for about half of the remnant wetlands in the Central Valley. Loss of wetlands has been so severe in the Sacramento and San Joaquin valleys that the Grasslands account for about one third of all remaining wetland habitats in the Central Valley even though the original area of the adjacent wetland habitat in the Delta and the Tulare Lake Basin were of greater size and provided habitat for much larger numbers of wildlife. In contrast to the wetland area remaining in the Grasslands, the Delta, which originally encompassed about 450,000 wetland acres, has only about 18,000 acres of wetlands remaining. Unfortunately these habitats occur primarily as sump areas that were created by levee blowouts during floods or as narrow strips of robust emergent vegetation adjacent to rivers and sloughs

Table 7. Status of existing wetlands in the California Central Valley, the Suisun Marsh, and the Delta, 1989.

Basin	Protected[1] Federal fee title	State fee title	Federal easement	Private	Total	Unprotected[2] (%)	Total
Sacramento	23,040	8,600	7,935	0	39,575	27,950 (41)	67,525
Delta	0	3,500	0	1,550[3]	5,050	4,300 (45)	9,350
Suisun	1,100	10,900	0	46,000	58,000[4]	0 (0)	58,000
San Joaquin	16,580	8,590	28,130	0	53,300	67,000 (55)	120,300
Tulare	2,300	12,105	0	2,325[5]	16,730	19,650 (54)	36,380
Totals	43,020	43,695	36,065	49,875	172,655	118,900 (41)	291,555

[1]Protected wetlands are those held in fee title by federal, state, or county agency or privately owned wetlands with perpetual conservation easement.
[2]Any privately owned wetland not covered by a perpetual easement.
[3]Consumnes Preserve owned by The Nature Conservancy modified from Central Valley Habitat Joint Venture Implementation Plant 1990.
[4]The entire 58,000 acre Suisun Marsh was protected by the Suisun Marsh Protection Act of 1977.
[5]Includes 1,425 acres owned by Kern County.

(Fredrickson et al. 1989, Fredrickson and Laubhan, 1991). This nearly complete destruction and high fragmentation of habitats has reduced wetland values of Delta habitats to minuscule amounts compared to historic values. Similar losses have occurred in the Tulare Lake Basin. Historically, Tulare Lake sometimes reached a total area of over 500,000 acres but today about 36,000 wetland acres are present in the Basin (San Joaquin Valley Drainage Program 1990).

Status of Grassland Wetlands

Wetland habitats within the study area largely fall within three general groups: vernal pools dominated by annual vegetation and temporary flooding regimes, seasonal marshes with annual and perennial vegetation, and tule marshes dominated by robust perennial vegetation with seasonal or semipermanent flooding. The distribution of these three types is distinct with the abundance of vernal pools concentrated at higher elevations and greater distances from the primary floodplain.

Vernal pools—Vernal pools are small basins that occur at higher elevations throughout the study area. The East Grasslands has an abundance of this wetland type. The undulating topography and porous soils of this region, in conjunction with the depth to ground water. determines the number of basins and the total area that is flooded. The hydrology of the vernal pools is driven by winter rainfall within the study area, whereas the hydrology of the tule marshes is strongly influenced by precipitation events outside the boundaries of the study area.

Many vernal pools were not subject to consistent riverine flooding, thus land use impacts that effect their hydrology are different than for tule marshes. The shallow nature and infrequent flooding of vernal pools make them especially vulnerable to activities such as land leveling, filling by sedimentation, and activities that influence groundwater level. Activities that lower the groundwater table either eliminate vernal flooding or change the length of the flooding regime.

Seasonal Marshes—Seasonal marshes are the most abundant type of wetlands in the study area. They are dominated by alkali bulrush, saltgrass, alkali heath, baltic rush and brassbuttons. Flooding of seasonal marshes is strongly influenced by flows from lateral streams including Los Banos Creek, Creek, Silver Creek, Mud Slough, Garzes Creek, San Luis Creek, and Orestimba Creek. Seasonal wetlands are normally dry by May. Many seasonal basins were not flooded naturally until winter rains began. Where seasonal basins are under intensive management, flooding of some basins may occur as early as September.

Tule Marshes—Tule marsh habitats were distributed within the floodplain of stream systems; the San Joaquin River being the most important and extensive floodplain habitat in the study area. Overflow from the river annually replenished tule marsh habitats. The area of inundation, and thus the number of basins and area flooded within the floodplain, was related to rainfall and snow melt in areas upstream from the Grasslands (Ogden 1988). In extreme cases the flooding also was influenced by overflow into the San Joaquin drainage from the Tulare Basin. Soils with high clay content are common within the San Joaquin River floodplain and have an important influence on the hydroperiod of seasonal and semipermanent marshes. Flooding in areas of soils having a high clay content are less influenced by ground water.

The historic hydrology of the river floodplain was changed forever with the conversion to agriculture, construction of dams, and development of the irrigation infrastructure. The capture of water upstream and its distribution via irrigation and agricultural drainage systems removed the natural flooding regimes that annually overflowed onto the floodplain and replenished the tule marsh system. Today these marsh systems would be even more limited in size and function without state, federal and private efforts. Although the original values and functions cannot be completely duplicated, intensive management provides opportunities to assure that viable wetland habitats continue to be an important feature of the San Joaquin Valley. A new infrastructure of water supply from wells and irrigation canals, along with water control developments such as levees and water control structures, are used to maintain and restore wetlands in the area. Federal, state and private entities have different priorities that provide different water regimes. Federal lands largely were purchased to meet the requirements of the Migratory Bird Treaty. State lands also are important in meeting state and federal mandates but hunting is an important component. Private wetlands are primarily duck clubs and hunting is critical to the maintenance of habitat. Each of these entities flood wetlands via intensive water movements and manipulations. Thus, some of the values and functions of the original system have been maintained as is evidenced by the extensive use by a large number of waterbirds. Emulating the natural hydrology including within season and among season fluctuations has the highest potential to optimize benefits for a diversity of wetland wildlife. However, incorrect application of water regimes and application of intensive management at the wrong time can compromise the health of the ecosystem.

Grassland wetland habitats are unique and of critical importance in California and North America because these remnant habitats are clustered and include a mix of ephemeral, seasonal, and semipermanent basins. The unique size and distribution of these wetlands within the Grassland Study Area have benefits that extend far beyond the boundaries of Merced County and the State of California. Migratory populations that move across the North American continent, as well as those that move into Central and South American, rely upon the resources provided in the Grasslands.

HISTORY OF WATERBIRD POPULATION CHANGES IN THE PACIFIC FLYWAY

PACIFIC FLYWAY

The Pacific Flyway is one of four flyways where cooperating federal, state, and provincial entities provide management direction to benefit waterfowl populations. The political boundary of the Pacific Flyway includes lands west of the continental divide extending from Alaska, southward through the western provinces of Canada and the Rocky mountain states, including western portions of Mexico. Because waterfowl do not follow political boundaries, populations using the Pacific Flyway also breed in areas such as the prairie provinces of Canada or locations in northern Asia that lie outside the area described as the Pacific Flyway. Historically, the Pacific Flyway held the highest concentrations of wintering waterfowl, but this Flyway had the smallest area of native wetland habitats even before man severely disrupted wetland ecosystems (Bellrose 1976). California and Mexico are of critical importance for wintering waterfowl because they provide habitats required by a majority of waterfowl species using this Flyway. Thus, any changes in the area or quality of habitat in California have the potential to influence the outcome of annual cycle events and subsequently the fecundity and mortality of waterfowl populations extending from the prairies of North America to northern Asia (Raveling and Heitmeyer 1989).

IMPORTANCE OF THE CENTRAL VALLEY

Historically, the Central Valley held some of the largest and most impressive concentrations of migratory waterfowl in the Pacific Flyway and North America as well. Early accounts are anecdotal but the descriptions of massive numbers of birds in the Sacramento Valley, the Delta, and the Tulare Basin were consistent even though numbers are vague and the species described might be unclear (Day 1949). As Central Valley wetland habitats were destroyed (Day 1949), there was concern for migratory bird populations extending back to the early 1900's.

California was more fortunate in maintaining large populations of wintering waterfowl into the 1970's than other areas of the United States. Undoubtedly, this was related to the distribution of breeding waterfowl that wintered in California. These populations largely are associated with the more western prairie provinces of Canada and the U.S. that were less affected by land-use changes influencing the area and quality of breeding habitats before 1970. Thus, considerable assemblages of waterfowl continued to congregate in the Central Valley before the 1980's.

Wintering waterfowl populations in the Central Valley have ranged from 8 to 12 million ducks and geese. Although total numbers have declined, the area continues to support 60 percent of the Flyway wintering waterfowl population. Thus, this area is extremely important as the southern terminus or intermediate stopover for Pacific Flyway waterfowl that are produced in the prairies and parklands of western Canada and the river valleys and deltas of Alaska (Kozlik 1975). For example, of 9 basins that consistently winter waterfowl in the Central Valley, the San Joaquin Valley holds 25 percent of the wintering waterfowl population (Heitmeyer 1989) and has 156,680 acres of the 291,555 acres of habitats available in the Central Valley (Table 7).

The significance of the Central Valley wintering habitats is apparent from the peak population objectives for the North American Waterfowl Management Plan (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986, Central Valley Joint Venture 1990). The goal for ducks in the Central Valley Habitat Joint Venture is a peak population of 4.7 million birds (Table 8). Further, the Central Valley provides habitat for 100% of the Aleutian Canada Geese (*Branta canadensis leucopareia*) and the Tule White-fronted Geese (Table 8), 80% of the Cackling Canada Geese (*B. canadensis minima*) and Ross' Geese, and 66.7% of the Pacific White-fronted Geese (*Anser albifrons*) and Tundra Swan (*Cygnus columbianus*) populations.

Table 8. Peak population objectives for wintering waterfowl established by the Central Valley Habitat Joint Venture relative to those of the North American Waterfowl Management Plan.

	Central Valley	North America	Central Valley as % of total
Total ducks[a]	4,700,000		
Mallard	531,000		
Northern pintail	2,800,000		
Total geese and swans[b]	875,000	5,701,000	15.3
Cackling Canada goose	200,000	250,000	80.0
Aleutian Canada goose	5,000	5,000	100.0
Lesser Snow goose	320,000	1,760,000	18.2
Ross' goose	100,000	125,000	80.2
Tule white-fronted goose	5,000	5,000	100.0
Pacific white-fronted goose	200,000	300,000	66.7
Tundra swan	40,000	60,000	66.7

[a]No winter goals for ducks have been established in the North American Waterfowl Management Plan.
[b]Reflects recent winter distribution patterns and adjusted for 25% annual recruitment.

GENERAL DECLINE OF WILDLIFE IN FLYWAY

Early reports of wildlife populations in the Valley are poorly documented, but suggest that wild species generally were abundant. Survival and reproduction apparently were high for many species based on the descriptions in these early but poorly documented reports. Clearly, the abundance and distribution of wildlife have changed dramatically since the first settlers reached the Valley over 200 years ago.

Change in size and diversity of wildlife populations is directly related to the changing landscape and the type and intensity of human activities in the study area. The pattern of land use over the past 200 years has moved through a series of stages that influenced plant communities and wildlife populations. Land-use changes were characterized by pulses of activities that impacted large areas or changed the intensity or type of use. The first major modification in native habitats resulted from intensive grazing by domestic stock. This land use changed the plant composition and structural features of the habitat. Nevertheless, areas that were grazed by domestic stock continued to provide open space as well as the required food and habitat for some species. More dramatic changes in the study area occurred where native habitats were converted to agricultural uses other than grazing. Conversion to rowcrops and orchards was far more devastating to the integrity of native habitats than grazing. Despite intensive agricultural practices that require annual cultivation, open space for some wildlife is provided in these agricultural environments. However, overall species richness and the density of many species are reduced greatly. The most severe loss of open space in the study area occurs when agricultural or remnant habitats are replaced by more intense uses where hard surfaces and buildings reduce open space and high levels of human activity create continuous disturbance to natural systems (Murphy 1988).

The biological diversity of the Grasslands likely was little impacted by the first human activity. Asian immigrants largely were hunters and lacked the technology to dramatically influence natural systems with domestic stock or the development of population centers. However, there is some evidence that their hunting activities, and some environmentally related changes, impacted large herbivore populations (Burney 1993). Early settlers had little impact on open space because populations were small and the culture was oriented around hunting. Likewise, the natural hydrology was not impacted because these early cultures lacked the technology to dam rivers or dig channels and did not practice agriculture or graze domestic stock.

Large mammals which require extensive areas of undisturbed habitat to survive and reproduce have been influenced the most by human impacts on natural habitats (Murphy 1988). Grizzly bears (*Ursus arctos*), free-ranging tule elk (*Cervus elaphus nannodes*) and pronghorn antelope (*Antilocarpa americana*) have been extirpated from the San Joaquin Valley for

Table 9. Mean number of selected waterfowl counted in the Central Valley, Suisun Marsh and Delta, winter 1978–87.

Species	Sacramento Valley	San Joaquin Valley (%)	Suisun Marsh	Delta
Mallard	314,712	30,438 (8)	15,221	4,667
Gadwall	11,698	23,137 (65)	602	25
American wigeon	403,038	10,913 (3)	9,318	847
Green-winged teal	16,336	90,479 (79)	6,913	961
Cinnamon teal	137	2,541 (94)	42	2
Northern shoveler	122,557	209,142 (58)	28,456	3,022
Northern pintail	1,429,698	238,191 (13)	60,347	141,190
Canvasback	11,735	2,036 (8)	3,446	7,056
Ring-necked duck	3,896	917 (14)	404	85
Ruddy duck	16,361	15,985 (43)	2,558	2,184
White-fronted geese	20,092	4,884 (9)	6,491	20,768
Snow/Ross geese	304,310	35,397 (10)	82	19,278
Cackling Canada geese	10,792	4,128 (23)	2,520	830
Aleutian Canada geese	360	1,035 (67)	72	59
Tundra swan	21,283	357 (1)	4	19,999

a considerable period. Clearly the reduced size and increasing fragmentation of native habitats in the study area have been foremost in the demise of these native animal populations. Today the smaller habitat remnants are only suitable for providing the necessary space for smaller species. These changes in habitat area and quality have been so extensive that smaller carnivores such as the kit fox are now being severely impacted by land-use changes and have reached a status of endangered.

Today, California remains one of the principal wintering and migratory stopover points for waterfowl using the Pacific Flyway in spite of great habitat loss. Historically, as many as 81 percent of waterfowl band recoveries in California were from waterfowl banded in Alaska (1948). The Central Valley is of foremost importance for migratory and wintering waterfowl, shorebirds and other waterbirds. Although the Central Valley composes only 11 percent of the land area of the state, the area consistently supports 60 percent of the total wintering waterfowl population of the Pacific Flyway.

IMPORTANCE OF GRASSLAND HABITATS FOR BIRDS

Although the most comprehensive information on bird numbers, distribution, and habitat use within the Grasslands relates to waterfowl and shorebirds, many other migratory birds also are dependent on habitats within the study area. Counts of waterfowl numbers date back to at least the 1940's but information on shorebird numbers, distribution, and chronology of use primarily is from the past 10 years, with the most complete census work between 1988 and 1993. Counts of birds including waterbirds and nonwaterbirds are inconsistent. Numbers and chronology of movements by neotropical migrants is lacking. In contrast, numbers and distribution of raptors are undoubtedly more complete than for groups other than waterfowl and shorebirds.

Waterfowl

Fifteen species of waterfowl commonly use San Joaquin Valley habitats in winter. Concentrations of 5 species of waterfowl account for more than 50% of the wintering waterfowl in California during the period 1978-87 (Table 9). Species using Grassland habitats extensively in winter include gadwall (65%), green-winged teal (79%), cinnamon teal (94%), northern shoveler (58%), and Aleutian Canada Goose (67%). More recently (1985-1989) wintering waterfowl in the San Joaquin Valley have declined (Table 10). For example, Gadwall accounted for 65% of the species in the Central Valley (1978-87) but only 34% in 1985-89. Northern pintail showed a similar decline from 13% to 6.7%.

Table 10. Midwinter (January indices of waterfowl in the San Joaquin Valley, the Central Valley, and the Pacific Flyway, 1985–89 average (percentages). From Bartonek, J. C., USFWS Office Migratory Bird Management 9/13/89.

	San Joaquin Valley	Central Valley	Pacific Flyway
Mallard	23,090 (4.9)[1]	295,559 (76.3)[1]	1,402,119 (21.1)[2]
Gadwall	15,722 (34.1)	40,781 (88.5)	55,687 (73.2)
Wigeon	6,480 (1.9)	264,390 (75.8)	489,026 (54.1)
Green-winged teal	50,868 (21.5)	215,076 (90.9)	279,668 (76.9)
Blue-winged teal	1,126 (34.4)	2,332 (71.1)	3,316 (70.3)
Cinnamon teal			
Shoveler	51,557 (20.9)	163,547 (66.2)	256,144 (63.8)
Pintail	55,800 (6.7)	715,377 (86.0)	945,085 (75.7)
SUBTOTAL DABBLERS	200,578 (9.5)	1,697,153 (80.0)	3,431,701 (49.5)
Redhead	176 (24.0)	189 (25.8)	20,285 (0.9)
Canvasback	2,184 (7.3)	3,297 (11.0)	42,411 (7.8)
Scaup	274 (0.3)	285 (0.3)	146,945 (0.2)
Ring-necked duck	1,810 (13.5)	12,273 (91.7)	21,793 (56.3)
Ruddy duck	13,751 (18.2)	25,186 (33.4)	86,991 (29.0)
SUBTOTAL DIVERS	18,674 (6.6)	42,121 (14.9)	503,205 (8.4)
TOTAL DUCKS	221,273 (9.2)	1,743,626 (72.7)	3,996,245 (43.7)
Snow and Ross geese	27,604 (7.5)	308,584 (83.7)	403,756 (76.4)
White-fronted geese	2,814 (3.9)	45,844 (63.9)	71,861 (63.8)
Canada geese	9,822 (15.3)	26,551 (41.4)	323,878 (8.2)
TOTAL GEESE	40,240 (8.0)	380,979 (75.4)	816,624 (46.7)
Tundra Swan	486 (1.0)	34,869 (71.4)	61,121 (57.0)
Coot	18,840 (18.0)	54,359 (51.9)	185,456 (29.3)
TOTAL WATERFOWL	280,839 (9.2)	2,213,833 (72.4)	5,051,006 (43.8)
Cranes	2,282 (31.2)	3,020 (41.3)	17,416 (17.3)

[1] % of 1985–89 Average Index for California
[2] % Pacific Flyway in Central Valley

Waterfowl that use the Grasslands during the nonbreeding period either use the Grassland habitats (1) as a southern terminus for their annual movements or (2) as a stopover site as they move to or from (e.g., northward staging white-fronted geese) habitats at more southern locations. Species such as the cackling Canada goose, Aleutian Canada goose, lesser snow goose (*Anser caerulescens*) and Ross geese (*Anser rossii*) use the grasslands as a southern terminus during their annual movements (Fig. 10). In contrast species such as the pintail (*Anas acuta*), white-fronted goose, and cinnamon teal (*Anas cyanoptera*) use Grassland habitats as a southern terminus but also as a stopover during movements to wintering habitats in Mexico (Fig. 11). Waterfowl also breed in the Grasslands, the most common nesting species are mallard (*Anas platyrhynchos*), gadwall (*Anas strepera*), and cinnamon teal.

Shorebirds

During the past decade there has been an increasing interest in waterbirds other than waterfowl. Shorebirds represent a group with high interest to bird watchers. These generally small waterbirds largely exploit shallowly flooded wetland habitats with little vegetation and excellent horizontal visibility. Recent surveys have identified at least 20 species that regularly use Grassland habitats with numbers ranging from a single bird of a rare species to over 100,000 birds of more common species (Kjelmyr et al. 1991, Table 11). Spring migration appears to be one of the most important

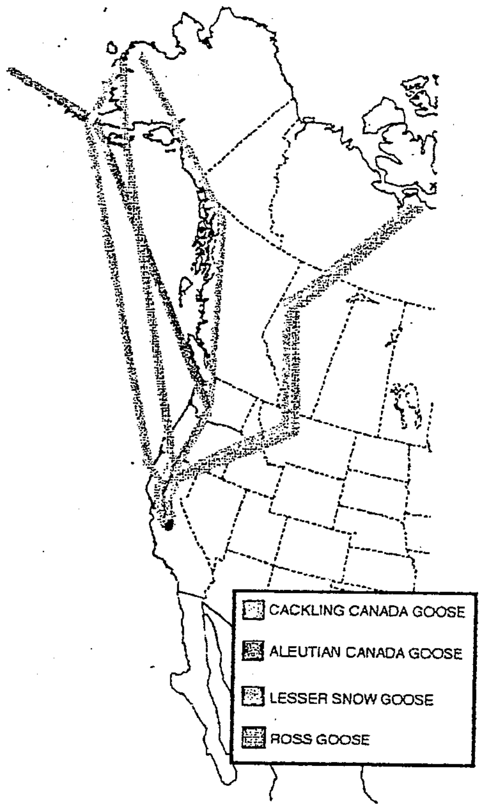

Fig. 10. Migratory movements of geese that use the Grasslands as a southern terminous during winter.

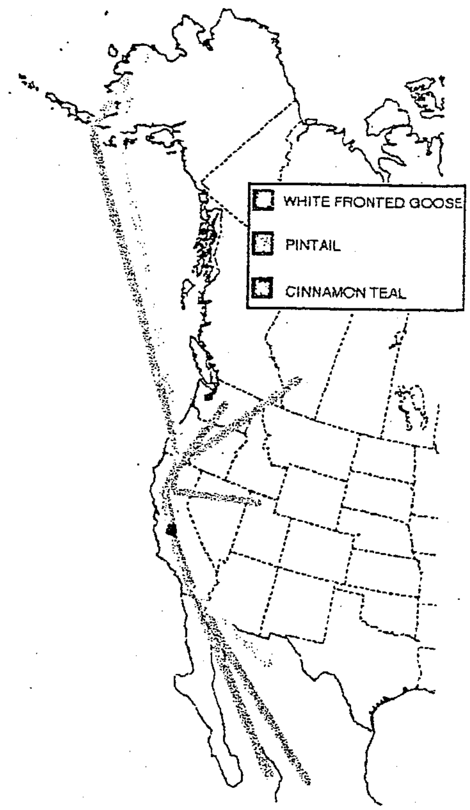

Fig. 11. Migratory pathways of 3 migratory waterfowl that use the Grasslands as a stopover area during migration or as a southern terminous during winter.

Table 11. Summary of shorebird populations surveys (1988-1990 and 1992-1993), Grasslands Wildlife Management Area.

Species	1988-1990 January	1988-1990 April	1988-1990 September	1992-1993 Winter
Black-bellied plover	582	3,190	653	2,795
Snowy plover	5	21	0	174
Semi-palmated plover	0	286	3	0
Killdeer	366	211	334	2,517
Black-necked stilt	4,038	3,024	2,634	6,179
American avocet	994	3,068	352	2,050
Greater yellowlegs	351	223	323	1,270[1]
Lesser yellowlegs	9	57	139	1
Solitary sandpiper	0	1	0	0
Willet	0	6	0	40
Spotted sandpiper	0		1	0
Whimbrel	0	187	0	0
Long-billed curlew	115	31	1,687	1,012
Sanderling	125	0	0	0
Marbled godwit	0	87	4	121
Western/least sandpiper	11,051	118,778	2,277	19,425
Dunlin	20,007	48,437	25	26,824
Dowitcher spp.	24,733	38,971	3,357	29,922
Common snipe	90	41	10	175
Red-necked phalarope	0	2	13	0
Ruff	0	1	0	0
TOTAL	62,466	216,624	11,812	92,517

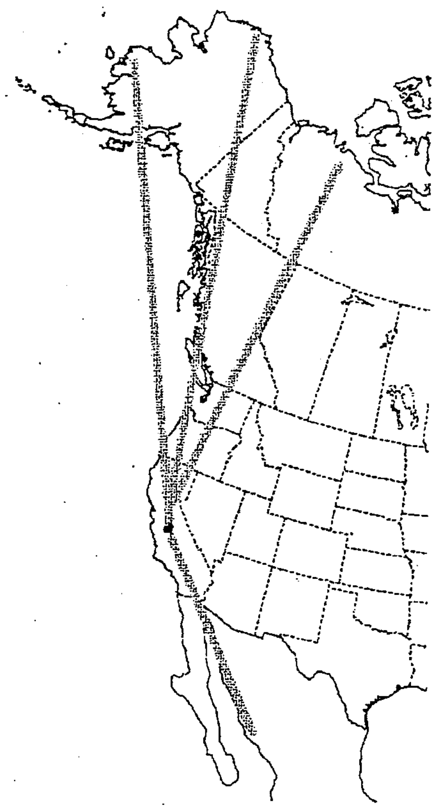

Fig. 12. Migratory pathways of shorebirds that use the Grasslands as a stopover area during migration or as a southern terminous during winter.

times of the year for shorebird use in the Grasslands. In part this is related to the timing of seasonal flooding of Grassland habitats. Most wetlands are not flooded until late fall and habitat is unavailable to fall migratory shorebirds, which typically begin southward movements as early as July (Fig. 12). However, Grassland habitats provide winter habitats to some shorebirds, including dowitchers, dunlins, and western and least sandpipers (Table 11). Peak numbers of shorebirds move northward in April and May on their way to Arctic nesting habitats. The abundance of suitable shorebird habitat in the Grasslands is high in April. Shallowly flooded habitats provide ideal foraging areas where presumably shorebirds acquire the necessary reserves for migration and successful breeding.

Three shorebirds, American avocet (*Recurvirostra americana*), black-necked stilt (*Himantopus mexicanus*), and killdeer (*Charadrius vociferus*), remain on Grassland habitats to breed. Annual production of young for these species has been estimated at 1,660 avocets, 2,000 black-necked stilts, and 4,000 killdeers.

Other waterbirds

Grassland habitats also provide important requirements for breeding, migrating, and wintering birds that are neither shorebirds or

Table 12. Waterbird use of West Grasslands (West Grasslands 1978).

Group/Species	Type of use	Average. production	Estimated number Average	Peak	Average duration of use(weeks)
Waterbirds					
Pied-billed grebe	b,w,f,s	60	250	1,000	52
Western grebe	w,f		25	100	26
Am. bittern	b,w,f,s	200	500	1,000	52
Gr. blue heron	b,w,f,s	700	1,000	2,000	52
Snowy egret	b,w,f,s	100	1,000	2,000	52
Great egret	b,w,f,s	100	300	500	52
Black-crowned night-heron	b,w,f,s	600	2,000	3,000	52
Lesser sandhill	w,f		5,000	12,000	26
California gull	w,f		1,000	1,500	26
Ring-billed gull	w,f		1,000	1,500	26
Common moorhen	b,w,f,s	600	2,000	8,000	52
Sora	b,w,f,s	400	400	2,000	52
Black tern	w,f		200	300	26
Whitefaced ibis	w,f		65	160	26
Subtotals			14,740	35,063	

b = breeding, w = winter, f = fall, s = spring

Table 13. Estimates of bird use other than waterfowl reported in the Grasslands(West Grasslands 1978)

Group/Species	Type of use	Average production	Estimated number Average	Peak	Average duration of use (weeks)
OTHER MIGRATORY BIRDS					
Brewers blackbird	b,w,f,s	4,000			52
Yellow-headed blackbird	b,w,f,s	600			52
Redwing blackbird	b,w,f,s	6,000	1,000,000	5,000,000	52
Tricolored blackbird	b,w,f,s	1,000			52
Starling	b,w,f,s	10,000	500,000	2,000,000	52
Burrowing owl	b,w,f,s	150	500	800	52
Great-horned owl	b,w,f,s		75	150	52
Short-eared owl	w,f			20	26
Marsh hawk	b,w,f,s		300	600	52
Red-tailed hawk	b,w,f,s	100	300	600	52
American kestrel	b,w,f,s	400	1,000	2,500	52
Red-shouldered hawk	b,w,f,s	20		10	52
Rough-legged hawk	w,f		2	12	26
Ferriginous hawk	w,f			1	26
Swainson's hawk	b,w,f,s	60	10	50	52
White-tailed kite	b,w,f,s	70	75	300	52
Prairie falcon	w,f		2	6	26
Sharp-shinned hawk	w,f		20	40	26
Golden eagle	w,f,s		6	15	39
Turkey vulture	w,f,s		35	100	39
Mourning dove	b,w,f,s	3,500		10,000	52
Total			25,900	1,507,325	7,025,204
RESIDENT WILDLIFE					
California quail	b,w,f,s	250	200	400	
Ring-necked pheasant	b,w,f,s	300	250	500	
Total		550	450	900	

b = breeding, nesting, brood; w = wintering; f = feeding;s = summer. Degree of accuracy of these estimates is unknown and some important species are missing including bald eagle, peregrine falcon, barn owl, marsh wren, and Cooper's hawk.

waterfowl. At least 15 waterbird species other than shorebirds and waterfowl use Grassland habitats, 8 of which breed in the area (Table 12). The most abundant are great blue heron, black-crowned night-heron (*Nycticorax nycticorax*), common moorhen (*Gallinula chloropus*) and sora (*Porzana carolina*).

Other birds

Although populations estimates are lacking for most other birds, some information is available for certain groups because of their potential to cause agricultural depredations or because they are threatened or endangered (Table 13). Raptor abundance and distribution probably are most complete because a large body size allows easier identification and census and there is concern for their status. In contrast, smaller birds often have secretive habits and are difficult to census. The most abundant group is blackbirds which total over 1 million birds on average with peaks exceeding 7 million.

Threatened and Endangered species

Intensive land use has resulted in widespread changes in numbers and distribution, as well as extirpation and/or extinction, of plants and animals native to California. Some species have disappeared from the state. In 1990 72 animals and 140 plants were classed as threatened or endangered. There is concern that 60 additional animals and 600 additional plants may face serious reduction or extinction (Department of Fish and Game 1991). Thus, remaining habitats, especially those of larger size, are of critical importance in maintaining the viability of species with decreasing populations.

The Grasslands study area includes habitats that are identified as having potential value to threatened and endangered species (U.S. Fish and Wildlife Service 1990, W. White pers. comm). Eleven species are listed as endangered by federal assessmant and include two reptiles, the blunt-nosed leopard lizard (*Gambelia silus*) and giant garter snake (*Thamnophis gigas*); two birds, the American peregrine falcon (*Falco peregrinus anatum*) and least bell's vireo (*Vireo bellii pusillus*); and three mammals, the San Joaquin kit fox (*Vulpes macrotis mitica*), Fresno kangaroo rat (*Dipodomys nitratoides exilis*) and giant kangaroo rat (*D. ingens*); 3 invertebrates, Conservancy fairy shrimp (*Branchinecta conservatio*), longhorn fairy shrimp (*Branchinecta longiantenna*), and vernal pool tadpole shrimp (*Lepidorus packardi*); and one plant, Palmate-bracted bird's beak (*Cordylanthus palmatus*). Threatened species according to federal standards in the study area include two birds, the Aleutian Canada goose (*Branta canadensis leucopareia*) and bald eagle (*Haliaeetus leucocephalus*); two invertebrates, valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) and vernal pool fairy shrimp (*Branchinecta lynchi*); and one plant, Palmate-bracted bird's beak, (*Cordylanthus palmatus*). The U.S. Fish and Wildlife Service and the state of California also have generated lists of proposed and candidate species that includes amphibians, reptiles, birds, mammals, invertebrates, and plants (Table 14).

The fauna and flora of the Grasslands have specific requirements that control reproductive success and survival. Collectively, the degree of individual success determines population size and fluctuations, as well as extirpations and extinctions. Over geologic time, extinctions and extirpations are common. However, human populations and their activities have created conditions that have accelerated changes in native animal and plant populations and distribution patterns. In fact, some scientists have stated that the rate of extinction is higher today than during the period when dinosaur extinctions occurred. Foremost among these perturbations are those that modify or destroy plant communities and the amount and distribution of open space. Thus, agriculture and urbanization are two of the most common threats associated with human activities that impact ecosystems and subsequently the size and distribution of wildlife populations (Murphy 1988, Warner and Brady 1994).

An understanding of these effects requires information on habitat requirements and chronology of use relative to life history events of individual species. In this report we focus on waterfowl life history requirements because of the high interest in this species group by individuals and agencies associated with the Grasslands. General requirements for a few select species other than waterfowl also are included. However, it must be remembered that successful completion of life history events for any species is dependent on ecosystem conditions. Thus, it is not possible to separate habitat perturbations from populations dynamics, nor is it possible to look solely at waterfowl species without considering other animal and plant assemblages.

Table 14. Proposed, threatened and endangered species in the Grasslands study area of concern to state and federal agencies.

Taxanomic Group	Species	Status Federal	Status State
Amphibians			
	California tiger salamander, *Ambystoma californiense*	2	CSC
	California red-legged frog, *Rana aurora draytonii*	1	CSC
	Western spadefoot, *Scaphiopus hammondii*		CSC
Reptiles			
	Blunt-nosed leopard lizard, *Gambelia silus*	E	E
	Giant garter snake, *Thamnophis gigas*	E	T
	Western pond turtle, *Clemmys marmorata*	2	CSC
	California horned lizard. *Phrynosoma coronatum frontale*		CSC
	Silvery legless lizard, *Anniella pulchra pulchra*		CSC
	San Joaquin whipsnake. *Masticophis flagellum ruddocki*		CSC
Birds			
	Bald eagle, *Haliaeetus leucocephalus*	T	E
	Peregrine falcon, *Falco peregrinus anatum*	E	E
	Aleutian Canada goose, *Branta canadensis leucopareia*	T	
	Least bell's vireo, *Vireo bellii pusillus*	E	E
	Ferruginous hawk, *Buteo regalis*	2	CSC
	White-faced ibis, *Plegadis chihi*	2	CSC
	Western snowy plover, *Charadrius alexandrinus nivosus*	PT	CSC
	Mountain plover, *Charadrius montanus*	2	CSC
	Black tern, *Chlidonias niger*	2	CSC
	Long-billed curlew, *Numenius americanus*	3C	CSC
	Fulvous whistling duck, *Dendrocygna bicolor*	2	CSC
	Tricolored blackbird, *Agelaius tricolor*	2	CSC
	California horned lark, *Eremophila alpestric actia*	2	CSC
	Loggerhead shrike, *Lanis ludovicianus*	2	CSC
	Western least bittern, *Ixobrychus exilis hesperis*	2	CSC
	Swainson's hawk, *Buteo swainsoni*		T
	Cooper's hawk, *Accipiter cooperii*		CSC
	Sharp-shinned hawk, *Accipiter striatus*		CSC
	Golden eagle, *Aquila chrysaetos*		CSC
	Northern harrier, *Circus cyaneus*		CSC
	Osprey, *Pandion haliaetus*		CSC
	Prairie falcon, *Falco mexicanus*		CSC
	Merlin, *Falco columbarius*		CSC
	Short-eared owl, *Asio flammeus*		CSC
	Long-eared owl, *Asio otus*		CSC
	Western burrowing owl. *Athene cunicularia*		CSC
	Greater sandhill crane, *Grus cancdensis tabida*		T
	White pelican, *Pelecanus erythrorhynchos*		CSC
	Double-crested cormorant. *Phalacrocorax auritus*		CSC
	Western yellow-billed cuckoo, *Coccyzus americanus*		E
	Willow flycatcher, *Empidonax flasiventris* (*traillii*)		E
	Yellow warbler, *Dendroica petechia brewsteri*		CSC

Table 14. (cont.) Proposed, threatened and endangered species in the Grasslands study area of concern to state and federal agencies.

Taxanomic Group	Species	Status Federal	Status State
Mammals			
	San Joaquin Kit Fox, *Vulpes macrotis mutica*	E	T
	Giant kangaroo rat, *Dipodomys ingens*	E	E
	Fresno kangaroo rat, *Dipodomys nitratoides exilis*	E	E
	Southwestern otter, *Lutra canadensis sonorae*	2	CSC
	San Joaquin antelope squirrel *Ammosperimophilus nelsoni*	1	T
	San Joaquin Valley woodrat, *Neotoma fuscipes riparia*	1	CSC
	San Joaquin pocket mouse, *Perognathus inornatus inornatus*	3B	
	Spotted bat, *Euderma maculatum*	2	CSC
	California mastiff bat, *Eumops perotis californicus*	2	CSC
	Arizona myotis, *Myotis lucifugus occultus*	2	CSC
	Townsend's western big-eared bat, *Plecotus townsendii townsendii*	2	CSC
	Badger, *Taxidea taxus*		CSC
Invertebrates			
	Valley elderberry longhorn beetle, *Desmocerus claifornicus dimorphus*	T	
	Conservancy fairy shrimp, *Branchinecta conservatio*	E	
	Longhorn fairy shrimp, *Branchinecta longiantenna*	E	
	Vernal pool fairy shrimp, *Branchinecta lynchi*	T	
	California linderiella, *Linderiella occidentalis*	PE	
	Vernal pool tadpole shrimp, *Lepidurus packardi*	E	
Plants			
	Palmate-bracted bird's beak, *Cordylanthus palmatus*	E	E
	San Joaquin Valley Orcutt grass, *Orcuttia inaequalis*	PE	E
	Hispid bird's-beak, *Cordylanthus mollis* ssp. *hispidus*	2	
	Delta button celery, *Eryngium racemosum*	2	E
	Colusa grass, *Neostapfia colusana*	PT	E
	Merced phacelia, *Phacelia ciliata* var. *opaca*	2	
	Bearded allocarya, *Plagiobothrys hystriculus*	3A	
	Heartscale, *Atriplex cordulata*	2	
	Valley spearscale, *Atriplex joaquiniana*	2	
	Slough thistle, *Circium crassicaule*	2	

E = Endangered
T = Threatened
PE = Proposed for listing as endangered
PT = Proposed for listing as threatened
1 = Candidate 1, FWS has information on taxa to support a listing proposal
2 = Candidate 2, listing may be appropriate, but FWS needs additional information to support any listing
3A = Species considered extinct
3B = Taxa no longer regarded as separate subspecies
3C = Taxa found to be more abundant than previously believed.

FUNCTIONAL ASPECTS OF THE GRASSLAND ECOSYSTEM

To understand the impacts of land use on wetland communities, a conceptual framework of wetland values and functions is essential. This section describes the intricacies of wetland habitats and the complexities animals face in meeting life history requirements.

WETLANDS: A CONCEPTUAL PERSPECTIVE.

Wetlands are best described as transitional habitats between aquatic and terrestrial systems where the water table usually is at or near the surface or the land is covered by shallow water (Mitsch and Gosselink 1993:25). Wetlands are characterized by having one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes (plants adapted to flooded conditions), (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. Wetlands classed as palustrine are the most common type in the Grasslands (Cowardin et al. 1979). Dynamic changes among seasons and years are characteristic of all wetlands where organic material, nutrients and energy flow into and from the system. Within the study area, the California Prairie surrounds the floodplain and is interspersed among depressions that are characterized as vernal pools, sloughs, and other wetland habitats. Uplands surrounding wetlands are integrally linked to the wetland basin or system. A conceptual model of wetlands (Fig. 13) depicts important biotic and abiotic components related to habitat values and functions of importance to wildlife. These components are surrounded by a dotted line

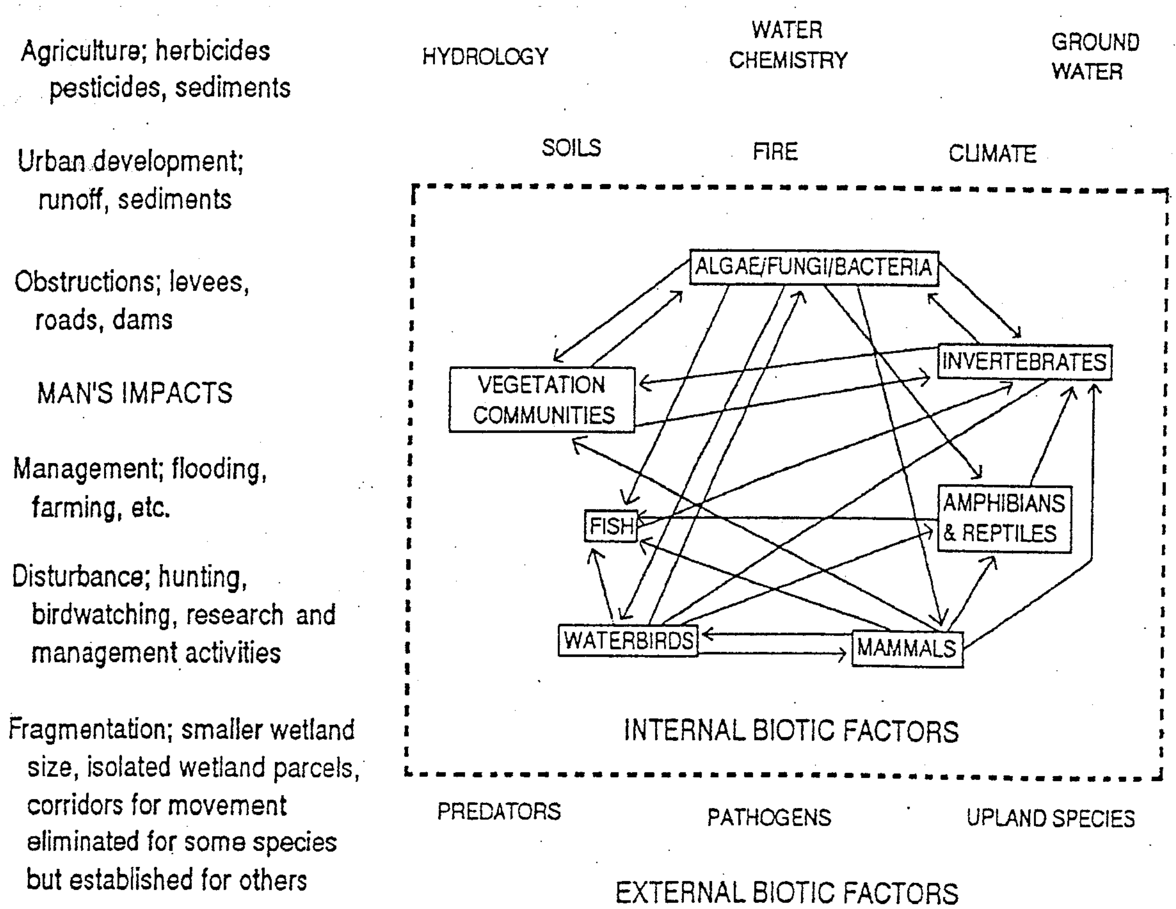

Fig. 13. A conceptual wetland model. The dotted line indicates the indistinct boundary of a wetland and suggests that energy and nutrients flow into and from the wetland.

to indicate the transitional nature of wetlands and to suggest nutrient transport into and from the system. In this model the wetlands in Merced County are used as an example of the important wetland ecosystem components between the Coast Range and the Sierra Nevada before development. Factors that influence these components fall into two distinct groups; Abiotic (non-living) and Biotic (living).

Abiotic Factors

Abiotic factors (e.g., physical and chemical) include hydrology, ground water, soils, climate, fire, and water chemistry. Foremost among these factors is hydrology because the time, duration, and depth of flooding not only control productivity of plant communities but also determine the value of habitats for myriad wildlife. Historically the hydrology in Merced County was influenced by flooding events that fall into two general categories: within Valley rainfall that occurs primarily in winter, and melt water from Sierra Nevada snowpack that primarily occurs in spring (Ogden 1988, San Joaquin Valley Drainage Program, 1990). The combination of these events created dynamic flooding conditions within Grassland wetlands. Wetlands at low elevations within the floodplain of the San Joaquin River had a high flood frequency whereas wetlands at higher elevations flooded less frequently.

The complex interactions among hydrology and climatic factors determine soil and water chemistry (e.g., salinity), which in turn influence plant community establishment and productivity, decomposition and nutrient cycling in Grassland wetlands. These factors directly influence the amount and type of food and cover available during the annual cycle of waterfowl and other wildlife.

Other factors strongly influencing wetland dynamics are related to mans' activities and include: agriculture practices; developments for irrigation and urban water; construction of roads, levees, and canals; wetland and wildlife management practices such as flooding, drawdowns, and farming; and urbanization and industrial developments (Fredrickson and Reid 1990). Agricultural practices have many impacts resulting in sedimentation, soil subsidence, accumulations of herbicides, pesticides, and fertilizers, pollution of agricultural drainwater with soils concentrations of elements such as selenium and boron. In California, human impacts that compromise wetland values and functions are as diverse, extensive, and intensive, if not more so, than those that occur in other states.

Biotic Factors

Biological factors, such as disease, predation, and competition, exert important influences on wetland community dynamics and productivity, which directly or indirectly influence waterfowl and other wildlife.

Components of wetland communities closely associated with wildlife use are: plants (algae, perennials, annuals), wetland macroinvertebrates, and decomposing vegetation. The dynamic interactions among biotic and abiotic components provide a basis for understanding land-use impacts on California's wetlands, thereby identifying opportunities to protect, restore and manage these important habitats. These different components have varying roles in providing food and cover for wetland wildlife. Each plant has its specific role or value in a wetland that is highly variable depending on the time of year and stage in the life cycle of the plant or animal. Some plants only provide food, others provide both food and cover and some play a major role only as cover. Additionally, plants are of critical importance in the nutrient dynamics within wetlands.

ALGAE AND DUCKWEED

Although poorly studied, algae and duckweeds respond quickly to readily available nutrients in the water column and can account for a large proportion of annual productivity. There is good evidence that algae plays an important role in tying up readily available nutrients thereby preventing export from wetland basins. Furthermore, algae are an important component in the decomposition process. Immediately after plant litter accumulates, algae colonize living and dead material and play a key role in conditioning the litter for macroinvertebrates. Algae serve as a source of food for many invertebrates and for some vertebrates as well (Euliss and Grodhaus 1987). For example, species such as American coot (*Fulica americana*) and gadwall readily consume algae.

ANNUAL MARSH VEGETATION

Annual vegetation characteristically is associated with portions of wetland basins that exhibit seasonal water fluctuations. Ephemeral, temporary, and seasonal wetlands, as well as higher elevations in semipermanent wetlands that are exposed during the hottest and driest portions of the year, typically have a predominance of annual vegetation.

Some of these annual plant species always are associated with wetlands, whereas during drier seasons or at the highest elevations within a basin annual vegetation classed as terrestrial is most likely to develop.

Common annual wetland plants in the Grasslands include watergrass (*Echinochloa* spp.), smartweeds (*Polygonum* spp.), swamp timothy (*Heleochloa schoenoides*), and sprangletop (*Leptochloa* spp.). Annual plants are particularly important as seed producers and species that have a complex plant structure such as smartweed also provide important substrates for aquatic invertebrates once they are flooded (Severson 1987).

PERENNIAL MARSH VEGETATION

Cattails (*Typha* spp.), hardstem bulrush (*Scirpus acuta*) and alkali bulrush (*S. robustus*) are typical examples of perennial marsh vegetation with a ubiquitous distribution in Grassland wetlands. Such robust plants serve a particularly valuable role in providing breeding habitat and cover for waterfowl as well as other waterbirds. The robust structure of these plants provides materials for nest construction, sites for nest attachment, cover from predators, and largely determine the cover/water interspersion that provides seclusion for pairs. This robust vegetation also provides important cover for broods. During other times of the year when weather conditions are harsh, tule marshes provide protective cover that appear to give birds a "thermal advantage". However, too much robust vegetation is undesirable. When dense monocultures of robust vegetation develop throughout a marsh system, the wetland loses value and use of the basin by waterbirds declines.

Some perennial marsh plants, such as hardstem and alkali bulrush, produce foods of value to wildlife. In contrast, some species produce abundant seed that is of little or no value as a food source for vertebrates because the seeds are too small or have a hard seed coat. Hard seeds are difficult to digest and often pass through the digestive tract intact (Buckley 1989). However, the underground parts and some fleshy plant material of these species may be used by some avian grazers (e.g., geese), muskrats and beaver.

Perennial marsh plants produce a tremendous amount of biomass annually. In prairie marsh systems cattails may produce 12 tons/acre/year. In most areas of California, these marsh plants senesce because of seasonal environmental conditions related to droughts or climate. Following senescence, this robust litter serves as an important nutrient source for certain invertebrate communities (e.g., substrate, food).

INVERTEBRATES

California's wetlands provide many habitat niches for invertebrates, which are important foods for many wetland wildlife. Furthermore, invertebrates play an important role in decomposition and nutrient cycling processes (Merritt et al. 1984, Reid 1985, Magee 1993, Fig. 14). Invertebrates have myriad life history strategies that allow them to exploit such diverse habitats as bottom substrates; submergent, floating and emergent vegetation; leaf litter from herbaceous and woody vegetation; accumulated organic matter; and the water surface (Minshall 1984, Fredrickson and Reid 1988a). Each habitat type has a distinctive invertebrate community that is adapted to the characteristic hydrology, vegetation structure, and water quality of the wetland basin. Because invertebrates are so abundant and serve as an important source of protein, they provide a critical nutrient link between detrital resources, plant community structure and wildlife (Batema et al. 1985). In the Grasslands, swamp timothy and watergrass provide habitats for invertebrate groups of importance to wildlife (Severson 1987).

Adaptation and response to natural hydrological regimes

Short and long-term hydrologic regimes have shaped the life history strategies of wetland macroinvertebrates. These strategies are based on adaptations of macroinvertebrates to tolerate or avoid drought. Adaptations that have evolved as a result of long-term hydrologic cycles require one or more of the following characteristics: (1) the ability to withstand drought in the egg, pupal or larval state; (2) rapid growth; (3) the ability to produce numerous offspring; (4) the ability to complete the life cycle within one year and (5) high mobility.

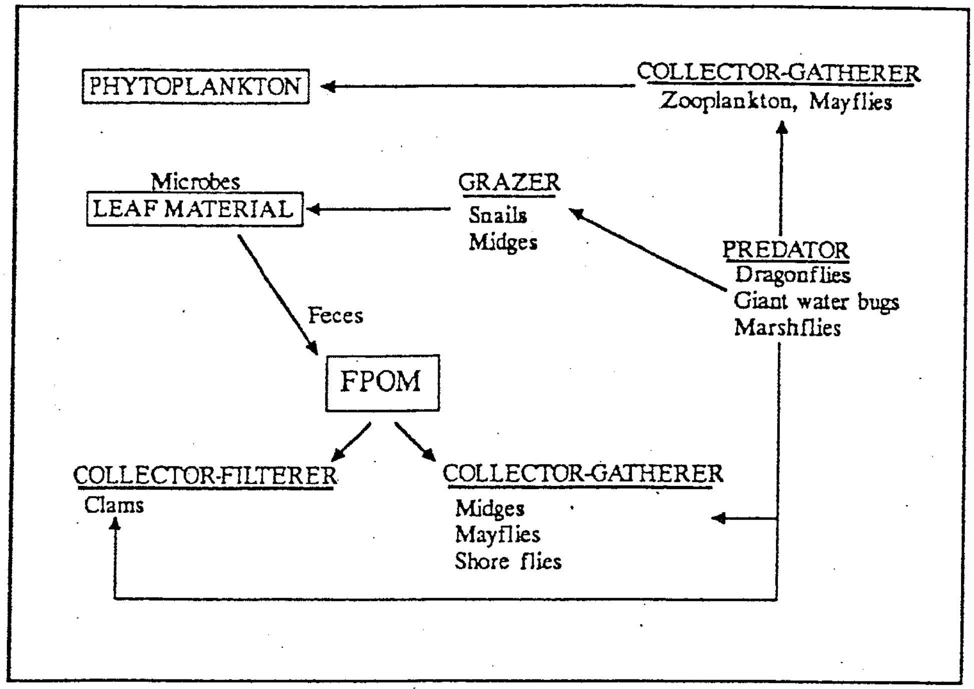

Fig. 14. Invertebrate functional groups associated with herbaceous seasonal and perennial marshes in the Grasslands.

The ability to withstand drought is an important characteristic shared by many macroinvertebrates that are common in Grassland wetlands (Reid 1985, Fredrickson and Reid 1988). Understanding life history strategies is important to predict how perturbations might impact invertebrate populations and their functional role in wetland systems. Several invertebrate groups including flatworms; fairy, clam and seed shrimp; water fleas; mayflies, mosquitoes; phantom midges; and marsh flies all represent species with drought resistant egg stages. In contrast, oligochaete worms may use muscosal secretions to survive drought, whereas chironomid larvae often resist drought by aestivating in cocoons. Fingernail clams rely on their shell to resist dessication, but also burrow into the wet litter layer to avoid predation, disease and drought. Isopods and amphipods have no morphological adaptations to resist drought, but will aestivate as adults and appear to find adequate moisture during the dry season within the deeper litter layers or in refugia that remain flooded.

Because of the dynamic nature of the flooding regimes in Grassland wetlands, macroinvertebrates that grow rapidly while water and nutrients are available have an advantage. Furthermore, producing large numbers of offspring and completing the life cycle within a year allow for greater success for each species. When water levels decline, species that cannot tolerate drought must be able to avoid dry conditions. Thus, species that avoid drought successfully often are highly mobile; either moving to deeper water or emigrating from the basin. Beetles and hemipterans, in particular, respond well to drawdowns by having an aerial dispersal to more permanent waters (Fredrickson and Reid 1988).

Although long-term hydrologic cycles influence adaptive strategies of invertebrates, their occurrence, growth and reproduction at any given time is determined by short-term water regimes and abiotic and biotic factors. The presence of wetland macroinvertebrates in newly flooded wetlands is apparent soon after inundation by floodwaters. Peaks in abundance are often dramatic and short-lived as invertebrates respond to fluctuating water levels and nutrient inputs. This general response of "pulsing" by invertebrate populations, although variable among years and habitat types, is typical of invertebrates that exploit fluctuating waters and nutrient rich detrital resources. Nutrients and organic matter are rapidly leached from leaf litter and detritus upon initial contact with flood waters. This leaching results in rapid increases in nutrient concentrations in standing water. Waterfowl that exploit macroinvertebrates as food resources are influenced by these dramatic invertebrate pulses. Thus waterfowl numbers and distribution during certain portions of the annual cycle partially reflect the abundance, availability and distribution of macroinvertebrates.

VERTEBRATES

Vertebrates are the most obvious and best understood members of wetland communities. They tend to have large body sizes compared to invertebrates and represent consumer groups at the upper end of the food chain (Fig. 15). Waterbirds represent the most visible vertebrate component because, in addition to a large body size, many species exhibit bright colors, high mobility, interesting behavior including songs and calls, and diurnal activity. In addition many birds often form large concentrations during winter or migration that regularly attract public attention. The most adaptable waterbird group is waterfowl because they fill many niches in wetlands; some primarily are herbivores, some are omnivores, while others are carnivores.

Frogs, toads, and snakes tend to be smaller than many waterbirds and are less mobile. Apparently amphibians are less adaptable to changing conditions or modification in wetland environments because their numbers have dropped precipitously at many locations across the continent. This group usually is less visible

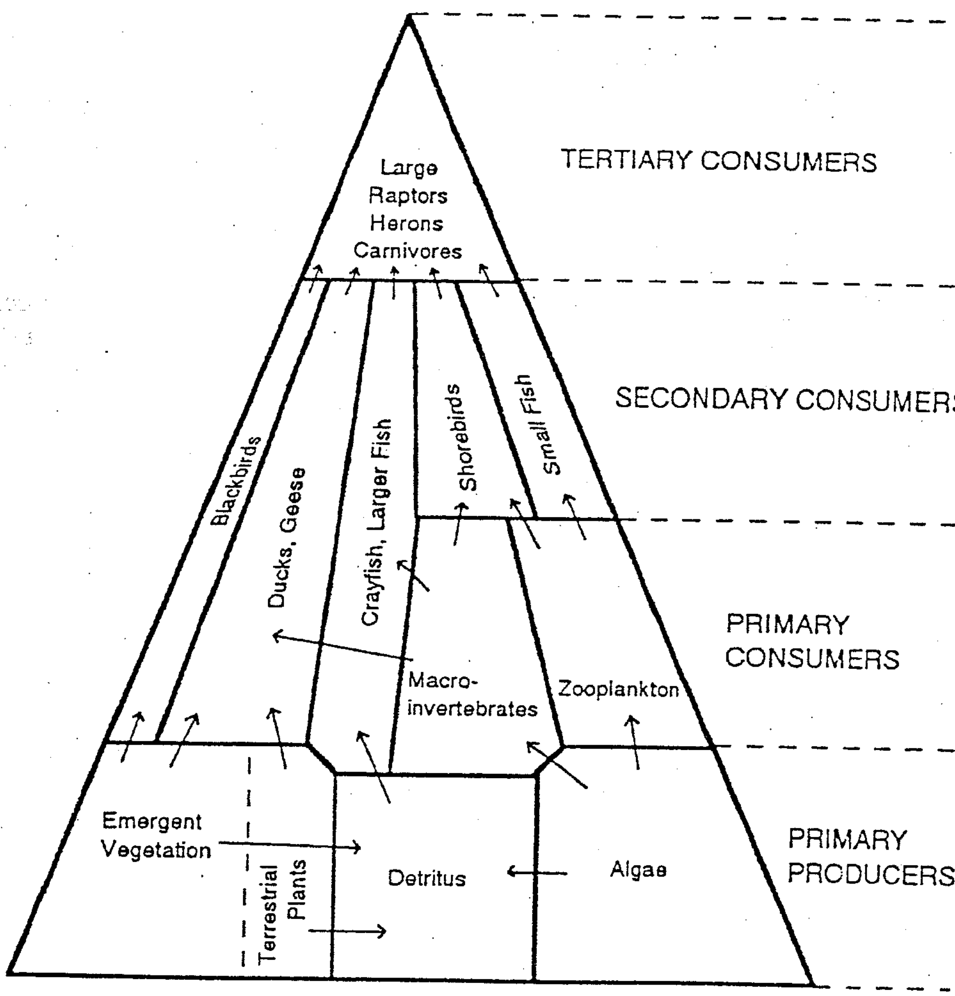

Fig. 15. Trophic pyramid of Grassland wetlands.

than birds because they tend to be nocturnal, only vocalize during the breeding season, and remain buried in mud, under water or in dense cover for most of their life cycle.Some reptiles (snakes and turtles) have been severly impacted by wetland loss and modification. The giant garter snake is an example of a federally listed threatened species present in the Grasslands. Fish are the other cold blooded vertebrates found in wetlands; but their abundance is limited in the seasonal wetlands, of the San Joaquin Valley.

Although mammals require water as a basic life requisite, few have completely adapted to aquatic environments (Weller 1987). The most abundant forms are herbivores such as muskrats and beaver. By comparison, carnivores are not abundant, but their predatory habits may have an important influence on other animal populations by influencing breeding success or mortality rates of young animals.

Vertebrates serve as the "canaries" in wetland systems. Their numbers, distribution, and reproductive success are indicators of wetland conditions. For example, listing of the giant garter snake suggests that some important habitats required for life history success have been compromised in the Grasslands. The distribution, size and fecundity of the less mobile vertebrate populations are the most sensitive indicators to changing wetland conditions, but many of these species are so poorly understood that detecting changes in populations or distribution is difficult. Birds serve as more obvious indicators of changing conditions because their numbers and distribution are much easier to document.

Birds are important consumers in the Grasslands study area. The abundance of herons and raptors is low compared to other bird groups because they are at the top of the trophic pyramid (Fig. 15). Ducks and geese are classed as primary and secondary consumers; whereas shorebirds are secondary consumers because they are predominantly carnivores. Because waterfowl have been so well studied, they will serve as a model to describe their role in the wetland system.

Waterfowl Life History Strategies

Waterfowl are well adapted to exploit the dynamic wetland and upland habitats associated with the Grasslands. Compared to

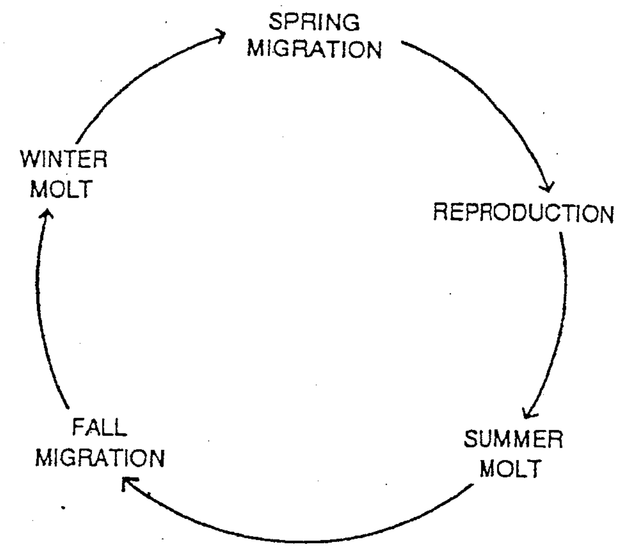

Fig. 16. The five major life cycle events of a typical dabbling duck such as a pintail.

other birds, waterfowl have large body sizes. Geese and swans are largest, and ducks are smallest (Bellrose 1976). Ducks vary considerably in size from the largest, such as mallards, to the smallest in North America, the teal. The large body size enables waterfowl to store a considerable amount of energy and/or protein that can be readily used for future needs. Thus, body size alone has an important influence on flight distances, fasting time, and thermal regulation. Furthermore, waterfowl are highly mobile and can move long distances in short time periods. This high mobility allows waterfowl to effectively exploit wetland habitats across the continent. For example, geese that breed in the far north migrate to the Grasslands for the winter where they use open habitats with good forage.

Waterfowl life history requirements occur as a continuum of events that overlap and are interdependent, and require diverse foods and cover (Fredrickson and Reid 1988b). A typical dabbling duck, faces five major energetic events during the annual cycle (Fig. 16) including reproduction, 2 molts, and 2 migratory periods. To successfully complete each of these events there are specific behavioral, physiological, habitat, and/or nutritional needs that must be met (Fig. 17). For example, the dietary needs for molt and migration are quite different (Fredrickson and Reid 1988b). Because feathers are high in protein, replacement requires large amounts of protein. In contrast, migration is an energetically expensive event that requires large lipid accumulation.

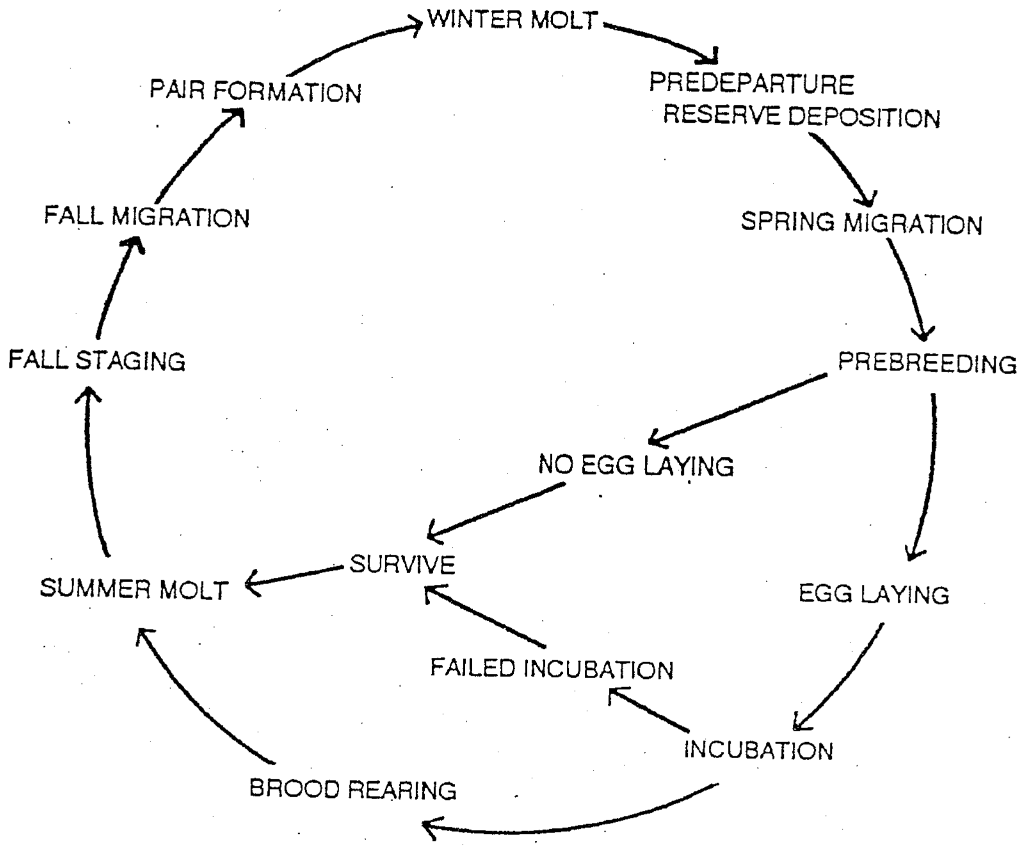

Fig. 17. The continuous sequence of events in the life cycle of a typical female dabbling or diving duck.

Thus, the foods necessary to complete both events tend to be somewhat different. A complicating factor in this senario is that molt and migration may overlap (Alisaukas and Ankney 1992). Thus, food and other components (e.g., habitat structure) necessary for both events must be available concurrrently.

Each waterfowl species that uses Grassland habitats has a somewhat different life history strategy (Fig. 18). These strategies range from arctic nesting geese that acquire necessary reserves on migrating and wintering habitats to the ruddy duck which primarily acquires necessary reserves on the breeding grounds (Owen and Reinecke 1979, Alisaukas and Ankney 1994). The locations where arctic nesting geese acquire the different components for breeding varies by species and population (Krapu and Reinecke 1992), but habitats outside the breeding area are important. Environmental conditions in different seasons and on widely separated habitats may have an important influence on the success of sequential activities in the annual cycle of waterfowl.

Mallard strategies differ from strategies of arctic-nesting geese. Most of the lipid reserves

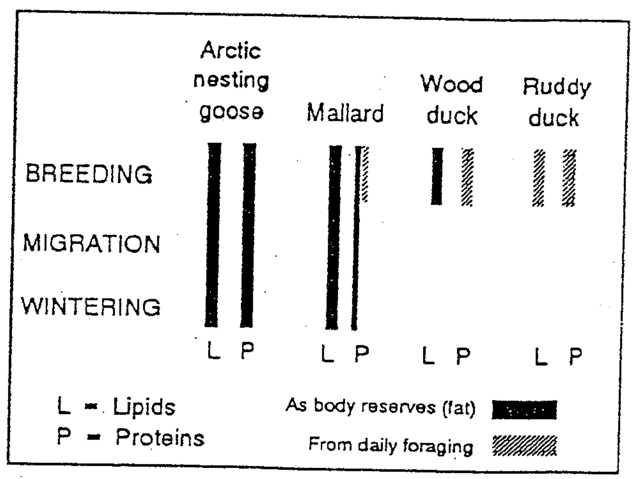

Fig. 18. Life history strategies of selected waterfowl showing when lipids and proteins are acquired from Grassland habitats.

and as much as half of the protein required for reproduction in mallards are transported to the breeding ground as body reserves (Krapu and Reinecke 1992). Wood ducks (*Aix sponsa*) and ruddy ducks (*Oxyura jamaicensis*) differ from mallards and geese because they acquire lipid and protein for reproduction primarily from breeding habitats. However, wood ducks acquire lipids prior to laying but rely on daily foraging for acquisition of all protein requirements (Drobney 1980).

Understanding these different strategies and the timing of these needs is important because land-use activities that compromise the size and quality of habitats can differentially effect the reproductive success of individual species (Raveling and Heitmeyer 1989, Nudds 1992).

Northern pintails are one of the most abundant species using Grassland habitats. Pintails either use the Grasslands as a southern terminous or continue into Mexico for winter. During their stay in the Grasslands, more than one event may occur concurrently (Fig. 19). Pintails as well as other dabbling and diving ducks have constantly changing nutritional requirements depending upon the stage in the annual cycle (Table 15, Connelly and Chesemore 1980, Miller 1987, Krapu and Reinecke 1992, Alisaukas and Ankney 1992, Fredrickson and Heitmeyer 1991). These diverse and constantly changing nutritional requirements must be met by exploiting diverse wetland habitats where the mix of plant and animal foods are readily available.

In the Grasslands, meeting this challenge requires attention to size and distribution of wetland habitats. Because no single wetland can provide all the energetic and environmental requirements for a single species during the annual cycle nor can a single wetland type provide requirements for a group of species, each acre of habitat in this disrupted landscape is important. These interrelationships among habitats to provide critical resources emphasize the importance of all habitats in western Merced County that surround the Grassland Water District. Wetland habitats are critical, but agricultural lands such as pastures and cereal grain fields are important in California because they add open space and foods required to successfully complete the annual cycle successfully.

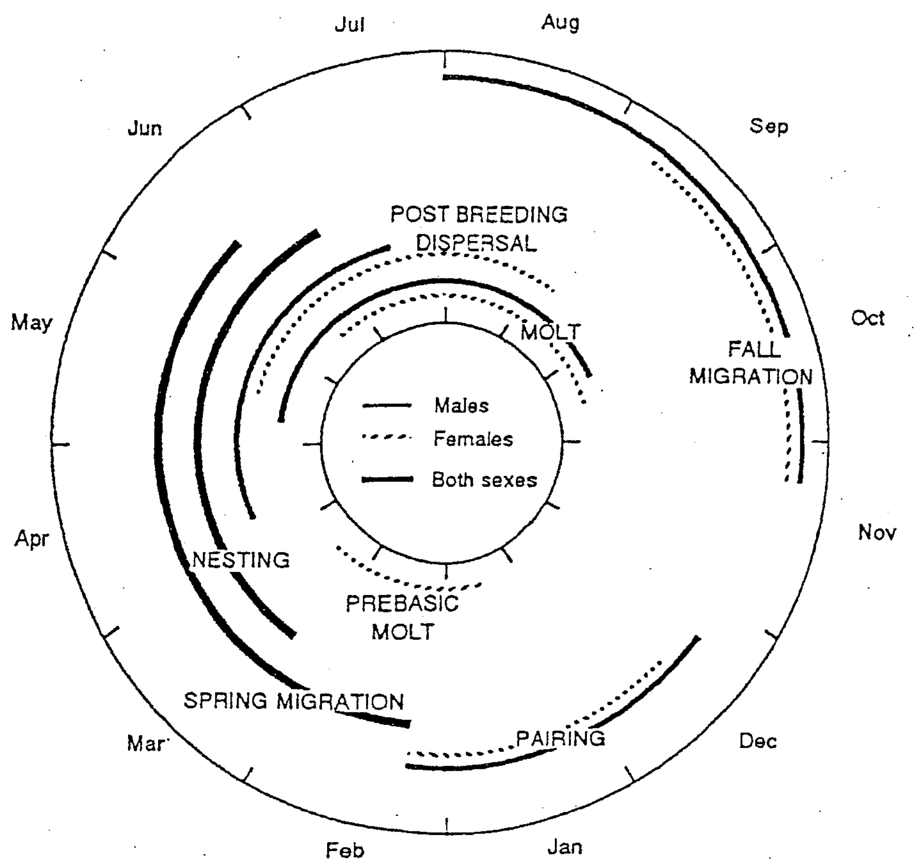

Fig. 19. Annual cycle of the northern pintail.

Table 15. General changes in nutritional requirements during the annual cycle of waterfowl.

Life stage	General needs	Specific needs: Geese/Swans	Specific needs: Dabbling ducks	Specific needs: Diving ducks
Premigration	High Energy	Plants-browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers Macroinvertebrates
Spring Migration	High Energy	Plants-browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers Macroinvertebrates
Prebreeding	High Protein	Plants-browse Aquatic tubers	Macroinvertebrates	Macroinvertebrates
Egg Laying	High Protein	Plants-browse Aquatic tubers	Macroinvertebrates	Macroinvertebrates
Brood rearing Early	High Protein	Plants-Browse Aquatic tubers	Macroinvertebrates	Macroinvertebrates
Brood rearing Late	High Energy	Plants-Browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers
Summer molt	High Protein	Plants-browse Aquatic tubers	Macroinvertebrates	Macroinvertebrates
Fall staging migration	High Energy	Plants-Browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers Macroinvertebrates
Pairing	High Energy	Plants-browse Aquatic tubers	Plants-seeds	Plants-Aquatic tubers Macroinvertebrates
Winter molt	High Protein	N/A	Macroinvertebrates	Macroinvertebrates

CURRENT KNOWLEDGE CONCERNING HABITAT FRAGMENTATION AS APPLIED TO THE GRASSLANDS STUDY AREA IN MERCED COUNTY

RATIONALE FOR CONCERN OF CONTINUED FRAGMENTATION/LOSS OF OPEN SPACE AND HABITAT IN WESTERN MERCED COUNTY

Historically, disturbed areas were surrounded by large areas of natural habitats and animals simply had to move around these small areas of disturbance (Csuti 1991). Today, the situation is reversed. Human impacts occur across the landscape and often represent the major land use in many geographic areas of the country, including the Central Valley of California. Such impacts are diverse and include agriculture, grazing, and mining, as well as transportation and utility networks, cities, and industrial areas. Many of these land uses have long-term, if not permanent, impacts that tend to isolate native habitats. As large blocks of contiguous habitats become segmented into smaller isolated parcels, any given parcel eventually reaches a size that cannot support viable populations of certain plants or animals and the final result can be local extirpation or eventually extinction (Wilcove 1987). Thus, many areas that once supported a diverse flora and fauna now only contain remnant populations of native species. As a result, an increasing number of scientists are reaching the conclusion that "habitat fragmentation is the most serious threat to biological diversity and is the primary cause of the present extinction crisis" (Wilcox and Murphy 1985:884). As natural areas continue to be disrupted by human activities, animal and plant populations become isolated in "island habitats" where genetic inbreeding, depredation of large species, and proliferation and domination of human-adapted species all interact to increase rates of extinction (Cutler 1991). An example sometimes used to illustrate the potential impacts of fragmentation, loss, and isolation of habitats are the declining populations of animal species on lands administered by the National Park Service. Forty-two species of native mammals have become extirpated on lands forming 14 parks even though these species were present when the parklands were established and they were protected thereafter from direct harm from humans and development (Chadwick 1991). Extirpated species include badger (*Taxidea taxus*), black bear (*Ursus americanus*), red fox (*Vulpes vulpes*), northern flying squirrel (*Glaucomys sibrinus*), beaver (*Castor canadensis*), gray fox (*Urocyon cinereaoargeteus*), spotted skunk (*Spilogale putorius*), ermine (*Mustela erminea*), mink (*Mustela vision*), and river otter (*Lutra canadensis*). The degree of negative impacts relating to continuing habitat fragmentation and loss is difficult to determine, but a recent study suggests that California alone may have 220 animal and 600 plant species threatened with serious reduction or extinction (Chadwick 1991). Although the exact cause of such declines in species diversity is not scientifically known, habitat fragmentation and isolation surely must be considered as important factors.

The importance of maintaining the integrity of the lands composing the Grasslands study area has not been fully quantified. Scientific evaluation and study of the short- and long-term impacts of habitat fragmentation on ecosystem functions is in its infancy. However, several pertinent statements can be made concerning past efforts at protecting species. First, we have learned that trying to maximize species diversity on every acre is not the solution (Samson and Knopf 1982). Second, it is inefficient to save selected species while allowing the natural communities and ecosystems that support them to deteriorate (Scott et al. 1991). Recent estimates (Erwin 1988; Wilson 1988) indicate there are more than 30 million species on earth, but a quarter of them may not survive to the year 2010 (Norton 1988). Most are insects that play critical roles in the function of natural ecosystems (Wilson 1987). Thus, the species approach to conserving biological diversity in the absence of habitat conservation is likely to fail (Hutto et al. 1987). For example, even though the federally endangered Aleutian Canada goose uses habitats within the Grasslands study area, our efforts should not be directed solely at providing what is perceived to represent suitable habitat for this species to the exclusion of all other species. We simply do not understand the synergistic interactions among abiotic and biotic factors that ultimately determine habitat characteristics. Thus, our efforts may fail if the system is not considered in its entirety. Finally, many human-related losses of biological diversity have been the result of simplistic notions of ecosystems and ecosystem processes (Cooperrider 1991). Often we assume that human ingenuity can diminish any impacts that change the landscape. Appreciation of the complexity of ecosystems will hopefully discourage the use of quick-fix, high-technology solutions without knowledge of their long-term impacts.

THE ROLE OF ISLAND BIOGEOGRAPHY THEORY IN MAINTAINING THE ECOLOGICAL VALUE OF THE GRASSLAND STUDY AREA

Although much site-specific information concerning the dynamic processes that govern habitat dynamics within the Grasslands is lacking, some general principles concerning habitat fragmentation undoubtedly apply. These principles must be incorporated into any decisions that may fragment or otherwise affect (e.g., habitat loss or degredation) the Grasslands. Foremost is the theory of island biogeography (MacArthur and Wilson 1967). Although originally applied to islands in the ocean, this theory has been applied successfully in cases where habitat "islands" are represented by isolated natural areas amid disturbed landscapes in the interior United States. Thus, the theory of island biogeography is applicable when considering potential fragmentation and habitat loss in the Grasslands. The primary tenet of island biogeography is the species/area rule; large geographical areas support a greater diversity and density of species than small geographic areas. Further, smaller islands exhibit a marked decrease in species diversity over time. A second tenet of island biogeography is the relationship between degree of isolation and diversity; the greater the isolation, the less the flora and fauna on an island have in common with the nearest similar communities. In general, if two "islands" are similar with the exception that one island is only one tenth as large as the other, the smaller island may be expected to hold only about half as many species and often far fewer (Waller 1991).

Although the statement that "the larger the area the greater the diversity and density of species" appears simplistic, there are underlying principles that tend to support the aforementioned tenets of island biogeography. First, the larger the geographic area, the greater the probability of encompassing a diversity of habitat types and microclimates that can support a diverse flora and fauna. This is particularly applicable in the Grasslands, which if viewed in a cursory manner, appears to be relatively homogenous in relation to topography and habitats. However, if examined meticulously, variations in plant communities and basin topography are evident within and among the lands east and west of the San Joaquin River and north and south of Highway 152. These variations largely may account for the differential use of waterfowl and other wildlife among the different regions composing the Grasslands. Second, the smaller and more isolated the geographic area, the greater the chance for extinction because: (1) isolated populations of species lack the genetic flexibility to cope with changes in the environment and their vulnerablity worsens as undesirable traits accumulate through inbreeding, (2) the greater the isolation the lower the probability that new individuals from other populations will immigrate into an area, and (3) natural catastrophic events (e.g., floods) can destroy a small island as well as entire populations of associated species.

The main principle of island biogeogrphy with regard to the optimum size of a contiguous land base has been summarized by Waller (1991):

> "We cannot tuck species away in little preserves, as if we were storing pieces in a museum. The essence of life is change. Organisms are constantly growing, interacting, adapting, evolving. Their numbers and distribution across the landscape fluctuate in cycles linked to climatic patterns and to other less understood rhythms. They are defined as much by their place in food webs and nutrient flows as by their own physical traits or any current geographic location. Many alter their range and behavior under different conditions. Some assume entirely new behavior through learning. In short, an ecosystem is not a collection of plants and animals. It is a seamless swirl of communities and processes. If the processes are not saved, the parts cannot be saved. Thus, if a preserve is to be created, it had better be a large one".

Although the "bigger is better" theory of island biogeography has been proven in several cases, the answer to "how big an area is needed" still remains ambiguous because of our lack of understanding concerning ecosystem processes and functions. However, many areas designated primarily for the purpose of protecting habitat/species are now known to be too small. For example, the oldest and largest national park in the West, Yellowstone, is not large enough to contain viable populations of many species, thus necessitating the need for management based on the "Greater Yellowstone Ecosystem" (Clark and Zaunbrecher 1987). Further, a number of national wildlife refuges with well-managed wetland habitat have become poor producers of waterfowl and other aquatic birds because so many eggs, nesting females, and young are taken by predators. (Waller 1991). The general public views these areas administered by Federal and State agencies as sufficient to maintain biological diversity. However, none of these areas are large enough to protect all the migratory species that use it. Regardless, such areas often are managed as if they existed in isolation. Surrounding seminatural lands are exploited for resource production at the expense of the substantial natural diversity they support (Cooperrider 1991). Such is the case in the Central Valley. The complex of national wildlife refuges (Kesterson, Merced, San Luis) cannot preserve or maintain a functioning ecosystem that supports a diverse biota on only 23,000 acres. In general, current preserve systems in the United States are of limited effectiveness by themselves because: (1) most were not established to preserve biological diversity (Blockstein 1989), (2) many preserves are not large enough to maintain viable populations of target species, much less self-sustaining ecosystems, and (3) no preserve is truly pristine or totally protected. Air pollution, exotic plants and animals, polluted water, and other "nonnatural" elements cross preserve boundaries as readily as they cross county lines (Cooperrider 1991). Rather, the integrity of the ecosystem and its associated value to wildlife is largely dependent on privately owned lands that constitute the majority of the Grasslands Study Area. In fact, it is widely recognized among resource agencies that private and multiple-use lands will be critical to conserving biodiversity. Some scientists have even stated that such lands are more important than parks and preserves (Norse et al. 1986; Wilcove 1988). How much destruction or degradation, if any, can occur before the "health" of the Grasslands is significantly impacted is unknown. However, past experience has shown that once the damage is done it is difficult, if not impossible, to reverse and repair. Therefore, any proposed alteration to the existing land base composing the Grasslands must be evaluated prior to implementation. Of particular concern is the planned urban encroachment that would further separate the north and south Grasslands into separate entities. Not only would new housing construction potentially impact the functioning of the current ecosystem, but the associated sewage treatment facilities, roads, powerlines, and domestic animals also represent important impacts. For example, boat and automobile traffic is the number one habitat-fragmenting force and the primary cause of human-related mortality for all of Florida's large threatened and endangered species (Harris and Frederick 1990); powerline strikes are major source of mortality of sandhill cranes in the San Luis valley of Colorado and of mute swans in Britain (Ogilvie 1966); domestic pets are known to seriously impact nesting success of many bird species; and the use of sewage effluent in wetland management can have differential effects on natural plant and animal communities depending on trophic level, type of nutrient enrichment, and stage of ecosystem development (Carson and Barrett 1988, Levine et al. 1989).

THE ROLE OF CORRIDORS IN MINIMIZING THE IMPACTS OF HABITAT FRAGMENTATION AND ROLE OF CORRIDORS

Many of the most significant human effects on biodiversity involve changes in the connectivity of biological processes (Noss 1991). Human activities may either reduce or increase connectivity. The consequence of some landscape modifications induced by humans have resulted in the creation of artificial barriers that hamper species dispersal (both plants and animals). The ultimate impact of creating such a barrier is the potential isolation of populations which become more vulnerable to extinction because of reduced access to resources, genetic deterioration, and increased susceptibility to environmental catastrophes and demographic accidents, among other problems (Harris 1984; Soule 1987). However, in other cases, human modification of the landscape have effectively eliminated natural barriers (Noss 1991). Although this may be viewed as beneficial, often degradation of natural barriers is detrimental. Floras and faunas that once were distinct and endemic can become dominated by unwanted exotics and cosmopolitan weeds (Noss 1991). The two most prevalent causes of such invasions are human transporation systems that facilitate the spread of certain species far beyond their natural dispersal capacities and habitat modification that favor weedy invaders (Elton 1958; Mooney and Drake 1986). The end result of this process is a homogenization of floras and faunas (Noss 1991). What is of critical importance is the fact that organisms differ in their dispersal abilities (Noss 1991). Thus, whether a given barrier alters species dispersal from one habitat island to another is dependent upon the life history of individual species (MacArthur and Wilson 1967). The same road that restricts movement of certain animal species may encourage movement of others. Likewise, certain types of corridors, whether created or maintained, could become avenues for the spread of exotic or pest species or lead to mingling of communities that normally would remain separate and intact. As a consequence, it is critical that the dimensions of the corridor linking the north and south grasslands be considered carefully, lest significant ecological impacts occur that are irreparable.

FACTORS IMPORTANT IN DETERMINING APPROPRIATE CORRIDOR DIMENSIONS

The role of corridors in preserving ecosystem functions is difficult to assess because little quantitative information exists. This is evidenced by the variety of definitions that have been applied to the term "corridor", including (1) a linear landscape feature that facilitates the biologically effective transport of animals between larger patches of habitat dedicated to conservation functions, including frequent foraging movements, seasonal migrations, or the once-in-a-lifetime dispersal of juvenile animals (Soule 1991), (2) any area of habitat through which an animal or plant propagule has a high probability of moving (Noss 1991), and (3) any naturally occurring or restored linear landscape feature that connects 2 or more larger tracts of essentially similar habitat and functions as either a movement route for individuals or an avenue for the spread of genes or other natural ecological processes across the landscape (Harris and Atkins 1991). Based on these definitions, the primary difference between a corridor and habitat is that corridors provide only life requisites necessary for travel, whereas habitats provide all life requisites. Regardless of definition, it is known that natural landscapes are basically interconnected and that connectivity declines with human modification of the landscape (Godron and Forman 1983; Noss 1987a). Further, it has been proven that fragmentation does impact natural processes, and these impacts can sometimes be devastastating (Wilcove et. al 1986). Although no irrefutable proof exists that corridors are essential to preserving the value of remnant habitats, it is known that fragmentation and isolation of habitats is not beneficial. From our perspective, definition (3) is the best approach to viewing the corridor linking the north and south Grasslands and east and west Grasslands because it embodies connectivity of large tracts of land for the purpose of providing transitional continuity among habitats. Too often humans view habitats as separate entities, whereas in reality they are interacting, functional components of the landscape ecosystem (Noss 1987b). If processes integral to the functioning of the system are disrupted, the entire system may collapse even though they appear physically connected. Thus, connectivity of process is just as important as connectivity of habitat (Noss 1991). A prime illustration is the role of fire in the pinelands of the Gulf coastal plain (Noss and Harris 1989): "Fires periodically burn down gradual slopes and prune back wetland shrubs that otherwise would encroach from adjacent swamps. As a result, fire functions to maintain an open herb-bog community with an extremely diverse flora adjacent to swamps. If fires are supressed, or fire lanes are constructed that disrupt the hydrology of the slope-moisture gradient, its unique flora is destroyed". Based on such general information, destruction or modification of existing corridors should be avoided from an ecological perspective. Consequently, the most prudent decision is to prevent disruption of the existing corridor connecting the north and south Grasslands until sufficient evidence has been collected to determine the relative value of this area and the potential impacts caused by modification. Although current plans for urban expansion do not indicate that the corridor will be completely destroyed, leaving only a remant strip of habitat may not be sufficient if it is too narrow. In fact, evidence indicates that linear strips that are too narrow may function more as a liability because they often promote predation or increase the probability that alien species (i.e., species which do not naturally occur) will invade the site (Harris and Atkins 1991).

Unfortunately, current information regarding optimum corridor dimensions is scant. However, corridor width has been identified as a primary determinant of corridor function. Width determines the extent of the edge effect, which influences predation rates and the potential for invasion of alien species (Janzen 1986). In many cases, limiting the dispersal of opportunistic, invasive organisms (especially exotics) may be as important as enhancing the dispersal of native taxa (Noss 1991). Edge effects vary depending on habitat type, but can range from 200 to 600 yards in forested communities (Temple and Cary 1988, Wilcove et al. 1986). Width also determines the potential for a single natural disturbance (e.g., flood, fire) to sever the corridor linkage. Finally, width influences the movement of flora and fauna. The wider the corridor and the greater the contrast between corridor and the adjacent habitat, the more effective a barrier it becomes and the more likely the corridor interior will have a chacteristic assemblage of animal species (Johnson et al. 1979, Chasko and Gates 1982).

Although this information does not quantify the desired width of corridors, it illustrates that the "optimum" width varies depending on objectives, habitats, and species being considered. Thus, it is important to explicitly state the objectives of the corridor. A corridor can be tailored to the needs of specific species, but at the same time it must not compromise the viability of other species (Soule 1991). A thorough understanding of life history strategies of species using the area also is essential. Important factors to consider include movement (type, rate, and magnitude), demographics (birth/death rates), age, and sex of individual species; interactions among and within species (displacement, predator/prey relationships, territoriality, competition); and habitat requirements (composition/structure of plant communities, barriers to movement, effects of edges on mortality)(Soule 1991).

Although the current concern regarding the future of the Grasslands may be perceived as a struggle between waterfowl and human needs, the scope of concern actually is much larger. Waterfowl are only one component of a much larger ecosystem. A more appropriate question that must be addressed is "What are the long-term impacts to the species assemblages (plants and animals) that may result following modification of the landscape?". Because species diversity/richness of an area largely are dependent on various aspects of habitat (e.g., type, interspersion, juxtaposition, quantity, quality), maintaining existing habitat characteristics is a primary concern. If this is accomplished, the long-term health of the system (including waterfowl) will be better ensured. Thus, the entire grasslands entity, including the corridor, must be viewed at a scale that considers dispersal capabilities of plant propagules, for example, as well as waterfowl movements among habitats. Otherwise, a strategy that appears to maintain biodiversity in the short term may fail to preserve viable populations and ecological integrity over a longer time span (Noss 1991). Based on this perspective, and our views regarding the value of the Grasslands on a local, regional, and continental scale, the optimum corridor width would enable the full spectrum of native species to move between not only the north and south Grasslands, but also help ensure that migratory species that winter in the Grasslands arrive on the breeding grounds in the best physiological state possible.

IMPACTS OF AGRICULTURAL LAND USE ON NATIVE HABITATS IN WESTERN MERCED COUNTY

Agricultural activities largely were responsible for the initial changes that converted western Merced County from a natural ecosystem to a fragmented landscape. Early settlers in the Valley recognized its potential for agriculture and set in motion changes that converted natural wetland and grassland habitats to the intensive agricultural industry of the 20th century (Association of Bay Area Governments 1991). The intensity is apparent based on the agricultural income from Merced and the surrounding counties (Table 16). Fresno County has an annual agricultural income of over $2 billion whereas Merced and Stanislaus counties each approach annual incomes of $1 billion. The greater amount of prime farmland in Fresno County is reflected in the higher annual farm income and clearly indicates why there was a conversion from natural systems to agricultural uses (Table 16).

The first changes in land use were related to grazing by domestic stock. Although the pristine plant communities had already been modified before sizable numbers of European settlers moved into the Valley in the mid-1800's, more intense grazing by domestic stock in the late 1800's further changed the plant communities. Environmental variation among wet and dry periods, in combination with the onset of intense continuous grazing, further changed the plant communities. Dry-land farming was practiced widely. The intensive manipulation of soils as compared to grazing changed plant communities further. Conversion of native habitats and pasture to cereal grain production associated with dry-land farming provided cover for wildlife during a portion of the year, and waste grains served as an important food source for some wildlife.

IRRIGATION INFRASTRUCTURES

The value of irrigation was recognized in the 19th century, but complete development of the system was not completed until the middle of the 20th century. Improvements to the system continue today. The irrigation infrastructure impacted land use in Western Merced County in three important ways: (1) the amount of area used for intensive agriculture, (2) the extent to which the hydrology of natural streams was modified, and (3) developments serve as barriers or conduits for animal movements. The conversion of natural systems to intensive agriculture has already been discussed extensively in this report and needs no further explanation.

The effects of land-use changes in relation to flowage patterns of natural streams was mentioned earlier in this report but not discussed in detail. These changes in hydrology fall into two distinct situations: (1) modifications in drainage patterns at a distant location and (2) modification in flow of natural stream systems. Because

Table 16. Agricultural production, farmland area, and human populations in Fresno, Merced and Stanislaus counties, California.

	Fresno	Merced	Stanislaus
Agriculture production($)	2,270,170,000	942,482,000	881,336,710
Agriculture production (Rank in state)	1	6	7
Human population			
1988	600,000	180,000	330,000
2000	730,000	260,000	460,000
Urban land	65,064	17,257	38,165
Land use			
Prime farmland	31,749	4,738	19,699
Total farmland	55,045	18,678	25,133
% irrigated crops w/saline soil	43	68	6

most of the water available in the San Joaquin Valley results from winter snow fall in the mountains or as winter rainfall in the Valley, water storage projects were required to capture this water for use during the growing season. Reservoirs were built on all of the major streams flowing into the Central Valley and water primarily was transferred by canals (Figs. 4, 5 and 6). In some cases sections of natural stream channels were used or these natural stream channels were modified to enhance the transfer of water. The capture of water at distant points upstream from the wetlands in western Merced County changed the amount of water available to recharge wetlands. Modifications to the natural stream channels within Merced County was related to flood control projects and to the transfer of water for irrigation. The natural drainage patterns were modified further because agricultural drain water (tail water or subsurface water) must be transferred from the site of application to prevent soils from becoming water logged and to prevent accumulation of salts, toxicants, fertilizers, or trace elements. The canals supplying and draining irrigation waters extend over hundreds of miles in Merced County. They cover a considerable area and create a network of barriers for movement of land animals but may also provide conduits for movement of some species (Figs. 4, 5, and 6; Table 17).

WATER QUALITY

Agricultural activities have impacted water quality in many different ways in western Merced County. Soil disturbance during agricultural operations increases erosion and results in a heavy sediment load (Table 17). A portion of the herbicides, pesticides and fertilizers applied to agricultural fields move into waterways or into the ground water where they have toxic effects on food chains, cause eutrophication, or have direct toxic effects on humans or wildlife.

Irrigation practices have the potential to exacerbate salinity, drainage, and/or toxicity problems (NRC-Committee on Irrigation-Induced Water Quality Problems 1989). Some salts and trace elements are present in all soils and water, whether the water supply is from surface flows (local or imported) or pumped ground water. As irrigation water is applied, dissolved solids are added to the soil and various mineral salts and trace elements present in the soil are dissolved. In the San Joaquin Valley, irrigation water adds 1.62 to 1.77 million tons of total dissolved solids to the region annually (San Joaquin Valley Drainage Program 1990). Water and dissolved solids are taken up by plants, but some water passes below the crop root zone and carries dissolved solids into deeper soils and ground water. Depending on soil properties, the ground water table may rise to the level of the root zone. Crop production is threatened when roots are flooded with saline water. Where the ground water is very near the surface, evaporation and capillary action also can draw dissolved salts to the surface resulting in salinization of soils. Thus, depending on the elements involved, akalinity or salinity of soils and water increase. Increased salt levels in wetland systems compromise plant and invertebrate communities which in turn influence the numbers and types of vertebrates in the system.

One of the most insidious aspects of subsurface irrigation drain water is the mobilization of trace elements such as arsenic, boron, chromium, molybedum and/or selenium that potentially have toxic effects when they are present in elevated concentrations. This group of elements associated with marine sediments is present in the western portions of the San Joaquin Valley (U.S. Department of the Interior and California Resources Agency 1990). Irrigation water moving through fields in this region is particularly prone to incorporating these elements as part of the dissolved solids. Agriculture has taken two approaches to solve the problem of increased salinity in ground water near the root zone. Either lands are abandoned when they have high salt concentrations or the drain water must be removed via drainage ditches or through a subsurface drainage system. This drain water usually is discharged into surface waters. Thus, these potentially toxic elements are common components of drain water in the western portion of the San Joaquin Valley. Such trace elements are then transferred in drain water through the irrigation infrastructure and can spread well beyond their point of origin. Because these elements influence plant and animal growth and mortality, their presence in the study area is a challenge that requires constant monitoring and regulation to prevent areas of trace element concentration that will severely impact native food chains.

Table 17. Summary of the effects of different land use impacts in the Grassland Study Area

Land use impact	Effect on size of functional area	Functional corridors	Ecosystem function	Wildlife distribution	Hydrology	Wildlife life history events	Water quality
Agriculture	Major reduction in functional area	Disrupts riparian corridors	Destroys natural system Fragments habitats	Reduces native populations. Discontinuous distribution	Increased runoff	Disrupts required habitats	Increased sedimentation, Herbicides, pesticides, and fertilizers
Highways	Moderate/ small reduction in functional area	Establishes barrier in corridor for terrestrial and aquatic animals. Increases noxious plant dispersal	Fragments habitats	Promotes discontinuous distribution	Disrupts natural hydrology	Causes wildlife mortality	Oils, gas, rubber, garbage
Irrigation system	Moderate reduction in functional area	Disrupts corridor	Fragments native habitats	Separates populations	Changes flow patterns	Restricts movement and dispersion May cause mortality	Drain water has salts, chemicals, and toxicants
Urban expansion	Moderate reduction in functional area	Disrupts corridors	Fragments habitats	Reduces populations	Increased runoff	Displaces populations	Increased sediments and toxicants
Rural housing expansion	Major reduction in functional area	Disrupts corridors	Fragments habitats	Disrupts distribution	Increased runoff	Displaces populations	Increased sediments and toxicants
Wastewater treatment facilities	Small reduction in functional area	N/A	Disease potential to wild animal populations	Often concentrates certain species	N/A	Concentrates birds, causes mortality	Increased nutrient loading
Domestic pets	N/A	N/A	Increased predation	Mortality of wildlife populations	N/A	Causes mortality; disrupts activities	Pet waste increases nutrient load
Stormwater	Small reduction in functional area	N/A	Potential fragmentation	N/A	Increased runoff	N/A	Increased sediments and pollutants
Golf courses	Small reduction in functional area	Disrupts corridor	Destroys natural systems Introduce exotics	Reduces native wildlife populations	Increased runoff	Compromises life history strategies	Increased fertilizer, herbicides, and pesticides

TRANSPORTATION

Roads are critically important for transportation of people, supplies, equipment, and commodities. The effects of transportation systems on open space and ecosystem function is similar regardless of whether the primary purpose of the road is for agricultural or urban uses. Agricultural development in western Merced County required a transportation system to interconnect farms and ranches with supply centers and markets. Furthermore, major highways also interconnect larger communities with other population and commercial centers in California. Open land within the study area has been converted from agricultural and natural systems to alternative uses for transportation including railroads, airports, and highways. The most extensive use of land for transportation has been for roads and highways. Because the construction of roadways is expensive and because roads often follow the most direct route, highways often pass directly through valuable agricultural lands or native habitats rather than circumventing such areas. This is the case in western Merced County because road systems cut directly through wetlands, riparian zones, native lands, and agricultural areas. Thus, some areas of habitat were lost from the construction of roads and road right-of-ways.

In addition to the loss of open areas, the development of road systems fragment landscapes. Roads often disrupt the natural hydrology by transferring water along road ditches, by intersecting drainages, and by forming obstructions to or changing the flow pattern of water where movement is a sheet flow (Table 17). In addition, roads often function as barriers to wildlife movement and can result in significant mortality of some species. The highest mortality often occurs during annual periods of dispersal from wintering habitats or during reproduction. However, frogs, toads, and turtles often are very susceptible to mortality during the breeding season. Likewise, some mammals are more active during periods when young disperse or during breeding. Sizable numbers become roadkills during such dispersal. Disturbance from roads also affects the distribution of species (van der Zande et al. 1980). Some birds move a mile or more from heavily traveled highways (Madsén 1985). Plant communities also are influenced by roadways, primarily because transportation corridors also serve as corridors for plant dispersal.

In western Merced County, there are primary roads within and surrounding the study area that influence the movements, mortality, and distribution of plants and animals. Divided highways require the largest land area and create the widest barrier to movements and disruption of hydrology. One of the primary impacts of road systems on natural environments is the division of large parcels into smaller ones. Primary roads such as I-5 and California highways 152, 165, and 99 have the most severe impacts because of the width of the right away, volume of traffic, and amount of noise and air pollution. California highways 152 and 165 effectively divide the study area into north and south and east and west sections, respectively. Thus, severe fragmentation of the study area is related to these transportation corridors that pass directly through the Grassland study area.

SUMMARY

A combination of factors related to agricultural activities and a gradual urbanization of western Merced County changed the pristine character of the landscape. Native plant and animal communities largely have been replaced by planted pasture and crops and only remnant plant and animal communities remain. No single factor led to these changes, rather many factors in combination have resulted in the present condition of the remaining natural communities. Agricultural development was not possible without a combination of economic incentives or opportunities, technological developments for irrigation by agricultural interests in a semiarid environment, government programs and subsidies, and a social perspective that promotes conversion of wildlands to other uses.

IMPACTS OF URBAN LAND USE ON NATIVE HABITATS IN WESTERN MERCED COUNTY

LOSS OF OPEN SPACE ASSOCIATED WITH HOUSING

The increasing human population within western Merced County can be classed into two general categories: urban and rural. As human populations expand, more space is required for housing. New housing associated with this population growth can be classed as either high or low density developments (Council on Environmental Quality 1974). Low density housing developments occur within some incorporated communities, but they are most common on small rural acreages and are becoming increasingly common within the rural setting of the study area.

Urban expansion associated with incorporated communities and/or housing developments also is common in western Merced County. New developments where large numbers of individuals are packed together are appearing on every side of the study area. Urban population growth in this report focuses on the communities of Los Banos, Volta, Santa Nella, Gustine, and Dos Palos (Table 18). In contrast, rural population growth is the diffuse expansion of new housing on larger land parcels amongst the agricultural lands in the county. Both types of population growth have important implications in reduction of open space and continuing fragmentation of existing habitats. Further encroachment can be expected with the growth in population in western Merced County. Communities in the Grassland Study Area will grow and require more open space for this expansion

Rural population expansion

The effects of uncontrolled development of rural housing has severe impacts on natural systems because large areas of native plant and animal communities can be disrupted (Table 19). Likewise, rural housing can disrupt the agricultural environment and reduce open space and the value of agricultural habitats for wildlife. The expansion of rural housing is associated with individuals that enjoy country living either because they are in agribusiness and prefer to live on their properties, or have purchased parcels of a few acres. Individuals build houses and/or stables for horses, or some other type of stock, or they just enjoy having more property for their use. As more rural housing develops, the infrastructure for transportation and utilities constantly expands or improves with a concurrent fragmentation and decrease of open space (Table 19). Considerable expansion of rural housing is occurring in the western portion of the study area between I-5 and lands within the Grassland Study Area. Most development is immediately adjacent to developed roads where there is access to electric power. In some cases the developments are improvements to housing on agricultural lands. Such improvements are not changing the character of the fragmented landscape further (i.e., there is little or no additional conversion of agricultural lands for housing). The most troublesome expansion of rural housing in relation to reduction of open space and further landscape fragmentation in western Merced County is associated with the develop-

Table 18. Projected population increases for selected cities in Merced County, California (1990-2010).

City	1990	1995	2000	2005	2010
Dos Palos[1]	5,845	7,909	10,738	14.543	19,667
Gustine[2]	3,931	5,173	6,874	9.134	12,137
Los Banos[3]	14,060	17.110	20,810	25.320	30,810
Santa Nella[4]				1.150	
Atwater[4]				31.000	
Merced[4]				79.260	

[1] Merced County Association of Governments 1990. City of Dos Palos Draft General Plan. 146pp.
[2] Merced County Association of Governments 1992. City of Gustine, General Plan. 170pp.
[3] Grunwald and Associates. 1988. The comprehensive general plan for the city of Los Banos, California (4.0% rate of increase) Sacramento.
[4] Merced County Planning Department. 1990. Merced County Year 2000 General Plan, Merced County.

Table 19. Impacts associated with expansion of rural housing.

Impacts	Effects
Development of small parcels	Decrease in open space-habitat fragmentation
Construction site	Erosion and siltation from runoff
Access road construction	Erosion and siltation from runoff
Increase in imperious surfaces (roads)	Hydrologic changes - greater runoff
Increase traffic	Air pollution
Wastewater/Septic Systems	Ground and surface water pollution
Solid wastes and litter	Greater need for landfills
Domestic pets	Destruction of wildlife or disruption of life history events
Illegal hunting	Reduction in wildlife populations

From: Council of Environmental Quality, 1976

ment of small parcels that were formerly in agricultural uses such as pasture, rowcrop, or orchard. In some cases these developments are on sites that had natural values because they were not in agricultural production or the lands had never been extensively developed.

Such developments disrupt remnant plant communities and wildlife populations either by direct loss or by modification of the local hydrology, increased sedimentation, or perturbations that increase the import of exotic species. The construction of rural housing and other buildings is associated with some road development, improved drainage systems, hydrological modifications to wetlands, development of facilities for treatment of human wastes (septic systems), construction of additional obstructions to wildlife movements (i.e., fences), and development of lawns with the associated application of herbicides and pesticides (Table 19). These unplanned sprawling developments also generate more sediments than well planned high density developments (Fig. 20). With the addition of each house there is increased vehicular traffic on roads and an increase in general disturbance related to human activities.

Urban population expansion

In comparison to rural housing, the effects of urban housing on the study area are more severe at site specific locations, but the size of the impact area is smaller. Urban development has many of the same problems as rural development, but the problems are intensified. Within the study area, current and planned urban developments generally change open space from an agricultural setting to one that more completely restricts use or access by wildlife. Thus, the location of the housing developments in and near the study area is critical because of site-specific and associated effects of development in relation to the functions and values of the natural system. Sedimentation can be extensive (Ferguson 1978, Fig. 20) when vegetation is disrupted and is of concern near wetlands because water systems can be clogged, wetlands filled, and wetland functions compromised. There will be negative effects to the natural systems regardless of where the development occurs but the effects will be less severe as the distance between the developments and the study area increases. Continuing development of urban areas within and surrounding the Grassland Study Area will have increasing implications for the viability of the Grassland ecosystem (Table 20). Los Banos is the most critical site because of its

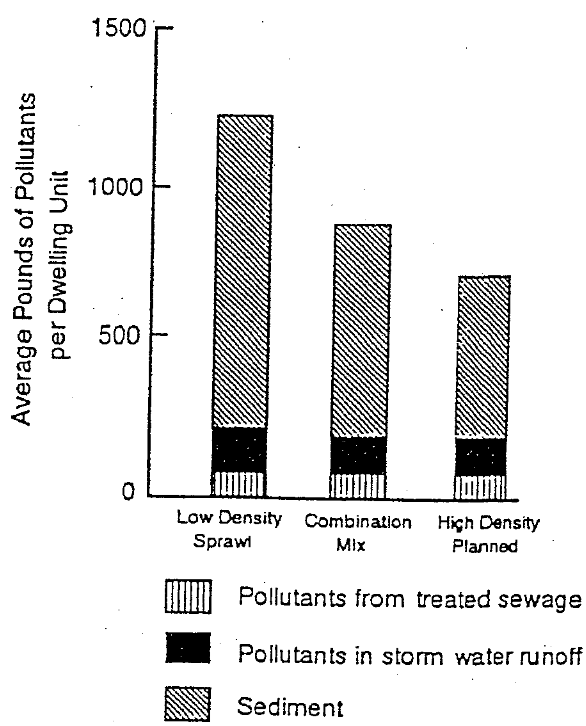

Fig. 20. Pollutants generated from dwellings of different densities.

Table 20. Projected effects of urban expansion in the Grassland Study Area of western Merced County.

City	Proximity to wetland habitat	Size of development	Corridor expansion	Projected population growth	Collective encroachment
Los Banos	+++	+++	+++	+++	+++
Dos Palos	+++	++	+	++	++
Volta	+++	+	+	+	+
Santa Nella	++	++	+	++	+
Gustine	+++	++	+	+	++
Atwater	+	+++	+	+++	+++
Merced	+	+++	+	+++	+++

size, location immediately adjacent to Grassland habitats, and the size and location of existing corridors.

TRANSPORTATION

Highways have been discussed under agricultural developments but transportation corridors are critically important for urban areas. Thus, the locations of urban developments that require road access have important implications in relation to functions and values of natural habitats.

WASTEWATER

Municipalities in western Merced County use effluent lagoons to treat wastewater. Several facilities are located adjacent to or within the Grassland Study Area, but the communities of Los Banos, Gustine, and Dos Palos have the most significant treatment facilities (Fig. 21). Impacts are related to changes in habitat conditions or to con-

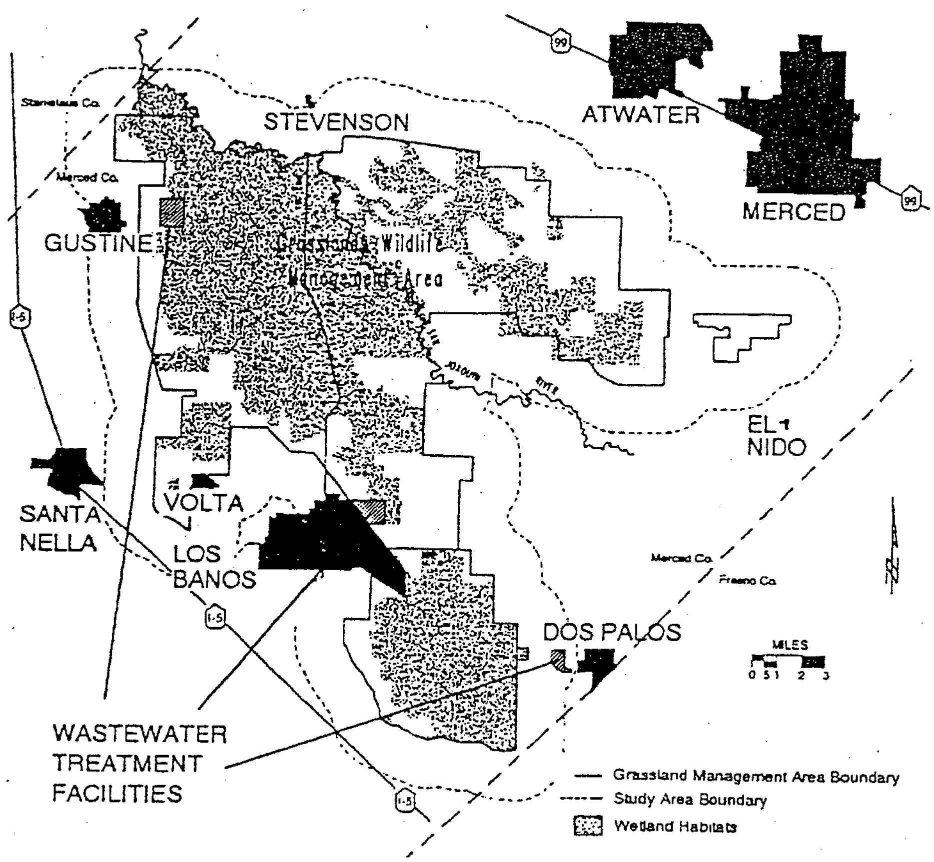

Fig. 21. Location of wastewater treatment facilities within and near the Grassland Study Area.

ditions related to operations of the treatment facility. In some cases wetland habitats or important open space for wildlife are converted to treatment facilities. Depending on the size, location, operation, juxtaposition to other habitats, local rainfall, and rates of evapotranspiration, operation of wastewater treatment facilities may have beneficial and/or negative impacts on wetland wildlife (Brennan 1985, Wilhelm et al. 1989).

Within the study area, much of the effluent that enters the treatment facility remains within the lagoons because evaporation rates are high in the San Joaquin Valley. Discharge into surface waters is restricted and excess water is typically applied to pastureland during the irrigation season (Brown and Caldwell Consulting Engineers 1989). The discharge of excess water laden with toxic materials, heavy metals, chlorine or materials with high organic matter or BOD often associated with urban effluent normally is limited to lands owned by municipalities in Merced County. Thus, wastewater treatment on the study area has limited negative impacts for wildlife as compared to other areas of the country where the combination of higher rainfall and lower evaporation require that considerable water be discharged (with the undesirable components) into surface waters to prevent damage to lagoons by uncontrolled overflows.

The potential value of wastewater facilities and use of wastewater for wetland wildlife has been identified for many years (Uhler 1956). Uhler discovered that waterfowl use of wastewater lagoons was widespread throughout many parts of the United States. A great abundance of some invertebrates has been identified as an important attractant for some waterbirds (Swanson 1977), and some treatment facilities have high densities of important invertebrate foods. Wastewater habitats are used by many waterbirds throughout the annual cycle (Uhler 1964, Swanson 1977).

Heavy use of wastewater facilities by waterbirds occurs in the study area in winter. Large aggregations of waterfowl occur regularly on the Los Banos and Dos Palos treatment facilities. Use of these treatment facilities probably is related to a combination of factors including extensive disturbance on wetland habitats during the hunting season, the security provided by the sanctuary effect of the treatment facility (little disturbance), and the abundance of certain food resources. Species that filter feed (northern shoveler) or feed on algae (gadwall, coot) tend to be the most abundant.

The concentration of waterfowl on treatment lagoons has negative impacts including the redistribution of waterfowl, and the potential for disease transmission. The most obvious and important impact of wastewater treatment in the study area is the concentration and redistribution of highly mobile vertebrates such as birds and the potential for avian diseases to be spread from these concentration areas. The treatment facilities in the study areas are of sufficient size to attract and hold sizable numbers of waterfowl (over 200,000 waterbirds, including 160,000 shovelers have been counted on the Los Banos treatment facility, California Fish and Game files, 1994).

Dense aggregations of waterbirds on wastewater lagoons have the potential for disease transmission (Friend 1985). Potential disease problems tend to be more severe from agricultural wastewater (especially poultry) than from urban wastes. Nevertheless, the lower water quality in wastewater systems in combination with the potential presence of pathogens has resulted in avian mortality in the San Joaquin Valley at the Modesto treatment facility (Zahm pers. comm.). Avian cholera is of primary concern because of the history of the disease in the Central Valley (Titche 1979, Friend 1989).

STORM WATER

Storm water runoff from urban areas includes many pollutants that have accumulated from industrial, commercial, and residential developments (Environmental Protection Agency 1977). The amount of storm water runoff is related to the area of impermeable surfaces such as roofs, driveways, roads, and parking lots (Huff 1977). The most common polluting materials from hard surfaces that occur in storm water or from street washing are rubbish, oil, gasoline, rubber, salts, and animal feces (Council on Environmental Quality 1974, Shaheen 1975). Sediments are another important component of storm water and are particularly abundant from construction sites or from exposed soils that are subject to erosion (Ferguson 1978, Fig. 23). Herbicides, pesticides and fertilizers are used heavily on residential lawns and gardens to protect or control household pests such as termites and other noxious plants, insects, or vertebrates (Environmental Protection Agency 1972). Rainfall removes air pollutants such as nitrates and sulfates from combustion which produces acidic water conditions. These contributions to storm water can contribute as much pollutant load as the sanitary sewage effluent (U.S. Department of the Interior 1970).

AIR POLLUTION

Air pollution is governed by two major factors: the presence of pollution generating sources and the inherent or modified meteorological conditions of the region. The region's meteorology determines the extent to which pollutants are imported from other regions and the extent to which locally produced pollutants are dispersed (Council on Environmental Quality 1974). Pollution sources generally are defined as point sources (e.g., a smoke stake from an industrial plant), ribbon sources (from highways), or dispersed sources (dispersed traffic and home furnaces and fireplaces). The major types of air pollutants are carbon monoxide, nitric oxides and oxidants, and sulfur particles and oxides. Vehicles emit carbon monoxide and the nitric oxides that chemically react in the atmosphere to form smog, whereas sulfur compounds are emitted primarily from fossil fuel plants, home and industrial furnaces, and certain industrial processes and incinerators.

Pollution from Vehicles

The extent of air pollution from vehicle traffic is related to the amount of travel, amount of congestion, and average length of a trip. Air pollution from vehicles varies during the day and generally is more severe in the morning when engines are cold, air is more static, and congestion is more severe as workers travel to their place of employment (Maga 1967). Thus, the development pattern in western Merced County can have an important influence on the frequency of travel and distances traveled. Because congestion is such an important aspect of air pollution from vehicles, providing even traffic flow on major roads by eliminating interruptions such as frequent access to the road from stores and homes, stop signs, and poorly timed stop lights are of great importance. Providing clustered and convient commercial areas and public facilities also eliminates the amount of travel.

DOMESTIC PETS

Domestic pets are an integral part of the environmental dynamics associated with human populations (Beck 1973). Regardless of whether pets are controlled or are free roaming, they can have an important influence on wildlife populations and their wastes have important implications in storm water runoff. Thus, as human populations change in size and distribution, populations of domestic pets must be one of the aspects considered in land use impacts.

Domestic pets also cause direct mortality of wildlife or disrupt life cycle events that reduce natality of wild populations (McMurray and Sperry 1941, Eberhard 1954, Parmalee 1953, and Toner 1956). Free roaming pets are of the greatest concern and cause the most interference with wildlife populations. Even in places where dogs are required to be on a leash a certain proportion run free. On a wetland in Britain, as many as 60% of the dogs were not on leashes, and of this total, 8% were running wild (Yalden and Yalden 1988). Dogs out of control, as compared to those "at heel", caused 7 times more red grouse to be disturbed (Hudson 1938). Thus, wildlife populations within the free roaming distances of urban pets are subject to high disturbance and mortality.

MOSQUITO ABATEMENT

Human populations have a long history of conflict with annoying insects that are associated with natural ecosystems. Mosquitoes are often abundant in wetland systems and are of concern to humans because they are vectors for transmission of human (e.g., malaria) and livestock (e.g., encephalitis) diseases. In addition, an abundance of mosquitoes are annoying to most individuals whether or not disease is a consideration. Thus, control of mosquito populations in the vicinity of urban areas has been practiced in the United States for many years. Control is achieved by habitat modification (drainage or level ditching of wetlands), by changes in water management (e.g., open water management), with chemicals, with biological control, or with a combination of these techniques. As human populations grow and as population distribution changes, there is an increasing demand to control mosquito populations.

Techniques used to control mosquitoes often are in direct conflict with the presence of wetlands and their natural functions. Drainage and/or hydrological modifications to wetland habitats, change plant and invertebrate communities that in turn influence other components in the system. Water management for mosquito control may compromise the life cycle of important invertebrates that play a role in decomposition or are important food for wetland wildlife (Balling et al. 1980). Availability of foods or habitats may also be compromised by water management designed for mosquito control. Non-selective chemicals can kill important invertebrate food sources and thus reduce the reproductive or survival potential of vertebrates.

The projected population increase for Merced County suggests that increasing pressure to control mosquitoes can be expected. The area of control and the type of control will have an important influence on the natural functions and values of Grassland wetlands.

Mosquito control is a factor in the management of Grassland habitats and will become increasingly important as the human population grows. From 1992 to 1994 there were nearly 1,000 requests for mosquito abatement in the North and South Grasslands (Table 21). About the same number of requests came from north and south of California Highway 152. Requests for control begin in April and gradually increase over the course of the growing season with the greatest number of requests occurring in October (Table 21). The Merced County Mosquito Abatement District applies Altosid Liquid Larvicide (ALL) and Duplex (ALL + *Bacillus thuringienses* var. *israelensis*) in aerial applications to Grassland habitats from August to October. The first application of ALL occurs during flood-up whereas the final treatment of Duplex is applied just before the hunting season in October. The final treatment on flooded wetlands controls *Culex tarsalis* and late *Aedes* hatches.

Table 21. Abatement requests made from 1992-94. North and South Grasslands are separated by Highway 152.

Month	North Grasslands	South Grasslands	Total
April	5	10	15
May	29	20	49
June	59	32	91
July	27	29	56
August	60	36	86
September	66	115	181
October	200	257	457
Total	446	499	945

The use of chemicals in wetlands, regardless of the purpose, is always of concern because of the potential to compromise the values and functions of these important habitats. This is especially true where habitats are limited and are subjected to other perturbations in addition to the effects of chemicals. Historically, the use of non-target chemicals in wetlands was disastrous because many desired species were impacted along with the noxious organisms. When biomagnification occurred in the food chain, organisms near the top of the food web often were affected adversely. As environmental concerns became more prominent, manufacturers have made an effort to develop chemical or biological controls that are effective on problem organisms but have little or no effect on desirable organisms. Not only have chemicals become much more target specific, but their biomagnification in food chains has been reduced or eliminated. Although these newer control methods are far superior there is still concern for the effects on vertebrates because of disruptions in the food chain. For example, experiments with mallard ducklings had slower growth and higher mobility (i.e., apparently they had to search for more food) immediately after treatment (Cooper et al. 1989).

One commonly used biological approach for mosquito control in Merced County is use of *Bacillus thuringiensis* (Bti), a potent bacterial larvicide. Toxicity is limited to nematocerous dipteran families, including mosquitoes (Culicidae) and blackflies (Simuliidae) (Krieg and Langenbruch 1981). The activity of *Bti* is dependent on the action of proteolytic enzymes within the gut. Because digestibility declines with age, older instars may be less susceptible (Maddox 1975). Abbott Laboratories provides a list of non-target aquatic organisms found in association with mosquito larvae but are not affected by *Bacillus thuringiensis* (serotype H-14). The list includes amphibians, fish, crustaceans, insects, flatworms, earthworms, and mollusks (Abbott Laboratories 1992). A study in the Midwest compared field and laboratory results using Vectobac-G or *Bti*, (serotype H-14, Charbonneau et al. 1994). In the lab, field treatment levels effected *Chironomus riparius* but there were not discernible effects on this chironomid in field tests. These results as well as other literature indicate that toxicity of Vectobac-G can vary. In this Minnesota study temperature, water depth, macrophytes surface area coverage, and instar differences affected the efficacy of Vectobac-G to benthic organisms (Charbonneau et al. 1994). Factors such as algal mats (Garcia et al. 1983), foraging by snails and other organisms (Aly 1983), and adhesion to leaves all influence the effectiveness of Vectobac-G. The effects of temperature are related to feeding rates (i.e., more feeding and thus greater ingestion of control agents when temperatures are high, Wraight et al. 1981 and Farghal 1982).

Information on Altosid or methoprene (Zoecon 1990) provides results from different tests (e.g., acute and subacute oral, acute dermal, reproductive, teratology) conducted to determine the effects of Altosid on different organisms, including rat, dog, rabbit, guinea pig, mallard, bobwhite, and chicken. No environmental persistence (half-life of 10 days or less) has been identified and no toxic effects have been observed in the field. Such testing is costly and cannot cover all species and certainly cannot address the complex conditions that exist in wetlands. Thus, the testing provides guidance in understanding the actions of the chemicals or biological control in nature, but actual results from field use can be highly variable. For example, water depth, temperature, pH, turbidity, amount and type of aquatic vegetation and substrate type are just a few factors that may change the effects predicted from laboratory experiments. These variable may cause the control agent to work more effectively or less effectively in relation to laboratory tests with similar variability in the response by non-target organisms to control agents. Furthermore the method of application is an important variable determining the effectiveness of control or the effects on non-target organisms. In addition to the effects of chemicals, the method of application can have important implications. For example, aerial application on flooded wetlands cause disturbance that have unknown effects on wetland wildlife. In contrast granulated material with slow release can be applied before flooding.

In summary, mosquito abatement strategies that reduce conflicts with wetland functions and values in the Grasslands will be an increasing challenge as human populations increase and encroach on wetland habitat. Unfortunately some of the effective control strategies for mosquitoes that do not include chemical or biological control agents, conflict with management designed to emulate natural hydrological regimes in seasonally flooded wetlands that are critical to the success and survival of wetland wildlife. Shallow water interspersed with vegetation provides the ideal habitat for invertebrate production as well as the desired foraging habitat for the majority of wetland birds. Because shallow water in association with vegetation creates ideal conditions for some mosquitoes, conflicts are inevitable. Thus, close communication, cooperation and coordination of efforts between mosquito abatement and wetland management interests are essential to reduce conflicts while meeting conflicting goals.

IMPORTANCE OF UNDERSTANDING HABITAT FRAGMENTATION AND ITS EFFECTS

The combination of factors related to human activities and land use in western Merced County now and in the future will impact the size, fragmentation, function and value of Grassland wetlands.

SIZE

As the population of Merced County grows, the projected population of 260,000 by the year 2000 will create an increasing demand for space that will be met by conversion of agricultural or native habitats to urban uses (Spaulding and Heady 1977). Pressures that result in decreasing size of functional habitats are greatest immediately surrounding the cities and towns in the Grasslands. As the size of a natural area diminishes, there is an important impact on the number of individuals and number of species that can survive within the smaller area of habitat (Geis 1974, Adams and Dove 1989, Fig. 22). The largest animals remaining in remnant habitats are those with the highest potential to be extirpated or to have reductions in populations.

FRAGMENTATION

Developments associated with urbanization have high potential to further fragment the remaining habitats. Increase in traffic will require upgrading highways and development of more transportation arteries. The current highway system in conjunction with the irrigation infrastructure already has an important impact on the functions and values of the natural system. The interconnection of habitats of the pristine valley has been disrupted by the transportation and irrigation corridors and other land use developments. Currently wetland functions largely are restricted to smaller parcels compared to the pristine condition. Fragmentation has important impacts for animals that require a large habitat area or those that have restricted mobility. The large carnivores and herbivores were eliminated from the Grassland ecosystem many years ago, but a continuing decrease in the size of habitat parcels because of fragmentation influences small carnivores and other moderate sized animals (Fig.

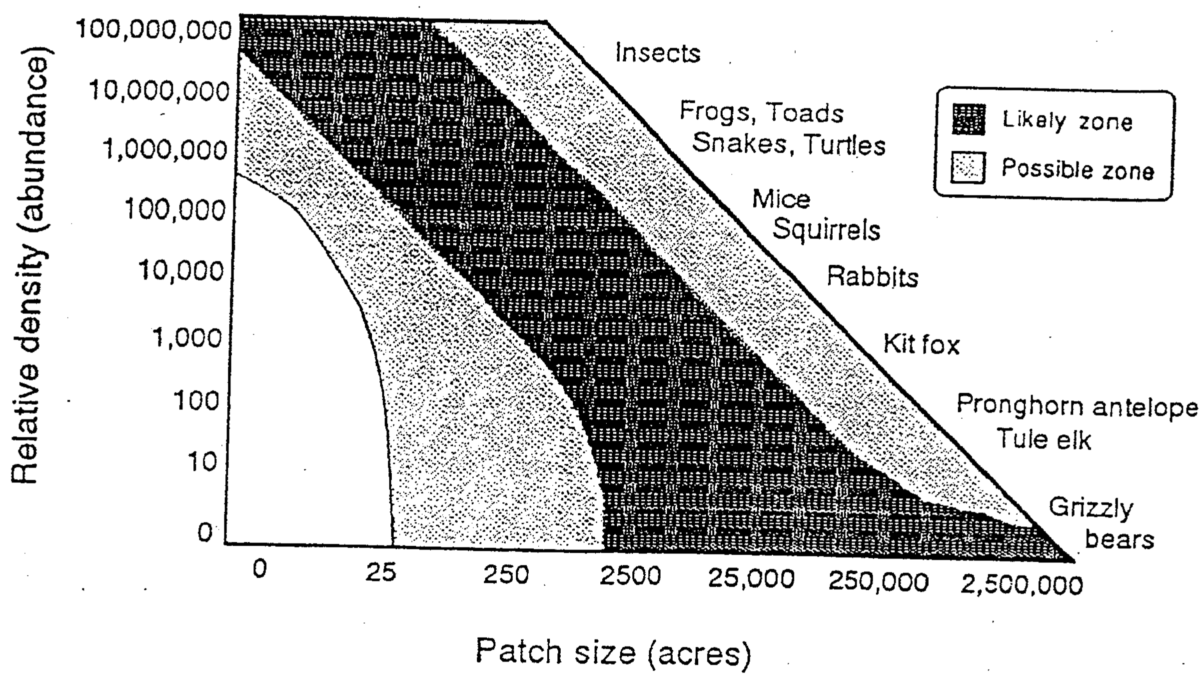

Fig. 22. Area of habitat required for the successful survival of different animal groups. From Soule 1991.

22). Birds have high mobility and can more easily move among isolated parcels. These movements increase energetic costs. Other factors associated with human population growth such as disturbance of wildlife, degradation of habitats and mortality of wildlife tend to decrease population size or compromise reproductive potential of wild populations.

Although the 180,000 acres in the study area apears to be huge, the actual functional area for many species is greatly reduced because of existing roads and towns. Clearly species with large home ranges have very few areas of suitable size for survival. Thus, a few additional activities resulting in fragmentation will impact many more species.

The impacts of size and fragmentation have important implications on the survival and reproductive potential of any species. The effects of fragmentation and decreasing habitat area are projected for waterfowl in western Merced County because waterfowl are of great interest in the study area and so much is known about waterfowl compared to other waterbirds (Table 22). Some effects are obvious, but many others are indirect or subtle and tend to gradually decrease habitat values for waterfowl. Thus the potential exists to further reduce waterfowl populations.

Table 22. Potential effects of fragmentation and reduced habitat size on the timing and/or completion of annual cycle events of a typical female dabbling or diving duck.

Life cycle event	Fragmented habitat	Degraded habitat	Reduced area of habitat
Pair formation	Less seclusion Pairing delayed Disturbance forces flight to alternate habitat	Required cover for pairing inadequate Inadequate foods to gain necessary body mass for pairing	Some pairing delayed Body condition inadequate for pairing
Winter molt	Inadequate area for seclusion; Disturbance disrupts foraging Molt delayed	Deficient food supply Molt delayed	Smaller food supply Molt delayed
Predeparture reserve deposition	Food supply distributed over large area Flight time reduces amount of energy for reserves Inadequate body reserves for migration	Deficient food supply Inadequate body reserves for migration	Smaller food supply Inadequate body reserves for migration
Prebreeding	Small patches of nesting cover, more predation likely	Lack of nesting cover Poor food resources	Reduced area for breeding; More predation likely; Poor food resources
Egg laying	Food resources widely scattered; More predation likely	Poor food resources More predation likely	More nest interference More predation likely
Incubation	High predation Female mortality	High predation Female mortality	High predation Female mortality
Brood rearing	High mortality from movements between habitat patches	Reduced food supply High mortality	Smaller food supply Predation higher than on larger areas
Summer molt	Inadequate area for seclusion; Disturbace disrupts foraging	Reduced food supply; Poor cover; Molt delayed	Smaller food supply; More predation
Fall staging	Smaller area for food production	Reduced food supply	Smaller food supply Molt delayed

NUTRIENT ENRICHMENT AND TOXIC SUBSTANCES

Chemicals from agricultural activities that enter surface or ground water influence the functions of wetland systems (Table 23). Agricultural chemicals have differing effects depending on the amount and type. Fertilizers that enter surface waters can cause eutrophication. The increase in algae production related to an abundance of available nutrients from agricultural fertilizers or runoff from livestock operations can change wetland plant and invertebrate communities. Depletion of oxygen from wetlands can change invertebrate communities, influence plant community composition and structure, and kill aquatic organisms such as fish.

The most common toxic materials in the Grasslands are herbicides, pesticides, and trace elements. Herbicides may have direct effects on plant communities, but indirect effects may influence animal communities as well. Herbicides can control the structure of wetland communities, reduce diversity, and disrupt the food chain for invertebrates as well as some vertebrates. Algae are an important component in wetlands because they quickly tie up available nutrients, are important in the decomposition process, and serve as food for invertebrates. Herbicides can compromise this important component of the food chain and result in a greatly modified trophic pyramid.

Pesticides from agriculture, urban household uses, and mosquito abatement programs have the potential to be toxic to aquatic organisms. Aquatic organisms have varying degrees of sensitivity to different chemicals. In some cases a certain chemical may have no direct impact on aquatic organisms. In other cases numbers of aquatic organisms may be reduced and in the most severe situations certain organisms may be completely removed from the system. Changes in the food chain are not readily visible because the physical structure of the wetland appears unchanged.

Trace elements have the potential to be toxic to consumers higher in the food chain. Elements such as selenium and arsenic can cause mortality or disrupt reproduction by increasing mortality or causing deformities.

DOMESTIC PETS

Domestic pets are one of the external biotic factors that influence wetland functions. Their most important influence on wetland communities is the potential to increase predation on adults and young and to disrupt life cycle events such as pair formation, egg laying, brood rearing, or dispersal (Table 23). The proximity of urban developments to native habitats is critical in relation to the severity of the effects on wild populations. The number of cats and dogs will increase along with the human population as Merced County becomes more urban. Thus, as the interface between urban sites and the Grasslands expands, domestic pets likely will increase. With more domestic pets, disturbance to wildlife will increase. This disturbance will increase energetic costs or compromise life history events for wildlife. In the worst cases, actual mortality of wildlife will occur.

GENERAL DISTURBANCE ASSOCIATED WITH HUMAN ACTIVITIES

Human activities intrude into wildlife habitats or disrupt life cycle events (Fig. 23, Table 23). The greater the human population the greater the potential for activities that will affect wildlife directly or indirectly. Some of the most obvious effects are related to activities such as hunting where some animals are harvested but a much larger number are forced to change their local distribution or move to more distant habitats. Other direct effects occur from disturbance (Korschgen and Dahlgren 1992). Depending on the time of year or stage in the annual cycle, disturbance may have a significant impact on wildlife populations. Disturbance might cause a redistribution of the population, emigration from the disturbed area, reduced time to acquire critical energy or nutrients, disrupt courtship, or cause reproductive failures (Owens 1977, Table 23). In areas of the highest use even trampling of vegetation can be a problem requiring years for recovery (Liddle 1975).

Table 23. Potential effects of land-use practices on wetland functions and values in western Merced County.

	ABIOTIC		BIOTIC				
			Plants				
Land use activity	Hydrology	Water quality	Algae	Macro-phytes	Inverte-brates	Herps	Birds
<u>Agriculture</u>							
Irrigation water storage	Changes timing and volume of flow	—	Area and volume of flooding reduced	Volume and area of flooding reduced	Less habitat flooded	Less habitat flooded	Less habitat flooded
Irrigation canals	Changes flow patterns	Transports salts and trace elements	—	—	—	—	—
Irrigation drain water	—	Concentrates salt and trace elements	Reduced biomass	Modify composition	Mortality	Mortality Deformities	Mortality Deformities
Herbicides	—	Adds non-point pollution	Reduced biomass	Reduced biomass and structure	—	—	—
Pesticides	—	Adds non-point pollution	—	—	Mortality	Mortality	Mortality
Fertilizers	—	Leads to eutrophication	Increased biomass Reduced species richness	Increased biomass Reduced species richness	Reduced species richness	—	—
Cultivation	Changes flow patterns	Increased sediments and pollutants	Reduced species richness	Reduced species richness	Smaller populations Reduced species richness	Smaller populations Reduced species richness	Smaller populations Reduced species richness
<u>Transportation</u>	Disrupt flow patterns	Increases pollutants and sediments	Reduced species richness	Reduced species richness	Reduced species richness	Mortality Disrupts movements	Mortality
<u>Urban</u>							
Stormwater	Changes flow patterns	Increases pollutants	—	—	—	—	—
Wastewater	—	Increased pollutants in discharged water	Increased biomass Reduced species richness	—	—	—	Concentrates birds Exposure to pathogens
Domestic Pets	—	Wastes increase pollution	—	—	—	Mortality	Mortality Disrupt life cycle events
Expansion	Changes flow pattern	Increased pollution streets, lawns, household and industry	Reduced species richness and biomass	Reduced species richness and biomass	—	—	—
<u>General disturbance</u>	—	—	—	Trampling	—	Disrupt life cycle events	Disrupt life cycle events

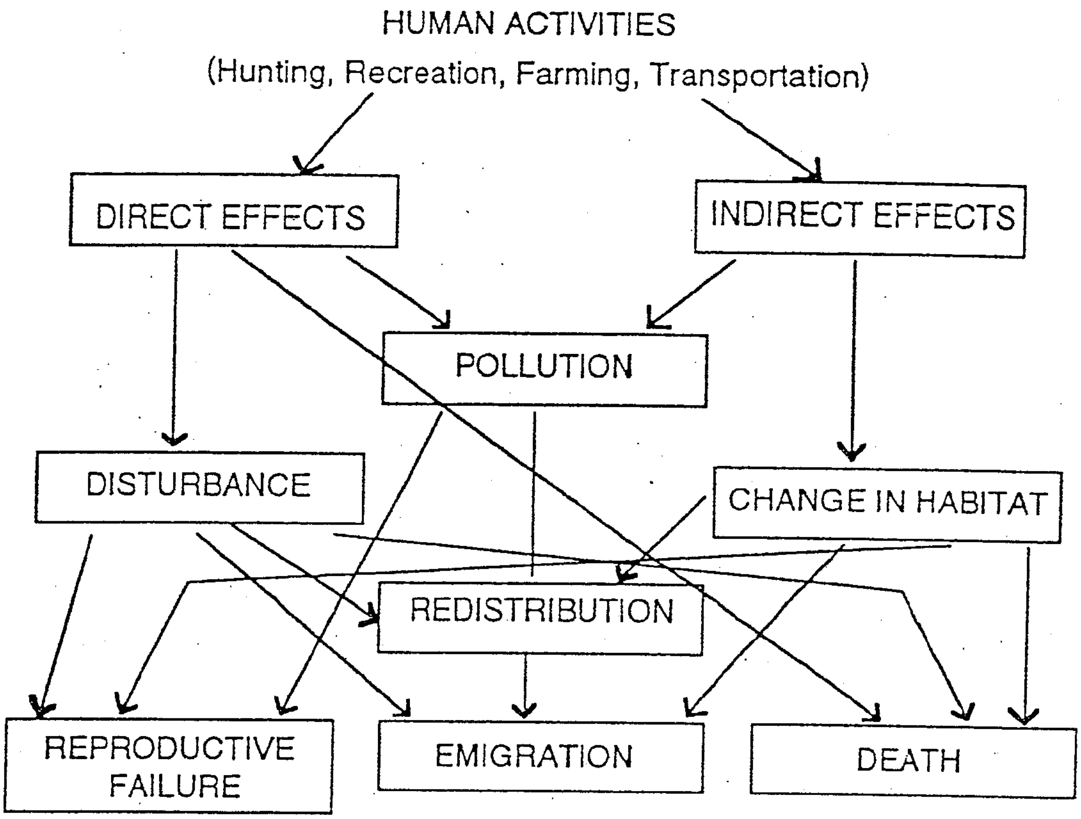

Fig. 23. Potential effects of human activities on wildlife populations.

GENERAL STRATEGY

The area and quality of Grassland habitats has declined significantly over the past 200 years. This decline, as well as major changes in plant and wildlife communities that have occurred did NOT result from a single factor but from a complex combination of factors driven by economics, legislative and political decisions, technology, and cultural or social implications (Fig. 24). Consequently, protection of remnant habitats requires more than a single faceted approach if future generations are to enjoy this remnant wetland ecosystem (Caldwell 1993, Clark 1979, Froke 1986). Creative methods must be developed that incorporate economic potentials, current and future technologies and social factors inherent to the area. This process has started and is clear from the shift in legislation from exploitive to protective mandates (Tables 3, 4, and 5). Additional efforts should include the identification and implementation of economic incentives, development of additional legislation, continued purchase and/or easements of important habitats, promoting changes in farm products, and educating the public regarding the importance of Grassland habitats.

FUNCTIONAL SIZE

The size of the Grassland Ecosystem must be protected. Size is one of the critical factors that determines whether a species has the space necessary to meet life history requirements. In addition, the type and diversity of habitats, whether natural or agricultural, is a critical component when determining the required size of an area. The relationship between habitat size and survival for each organism inhabiting the Grassland study area has not been established, but a clear relationship exists between the size of an organism and size of the home range essential for survival of a viable population (Fig. 22). Even though the Grassland study area encompasses nearly 180,000 acres, this is a minor fraction (4.5%) of the 4 million acres of

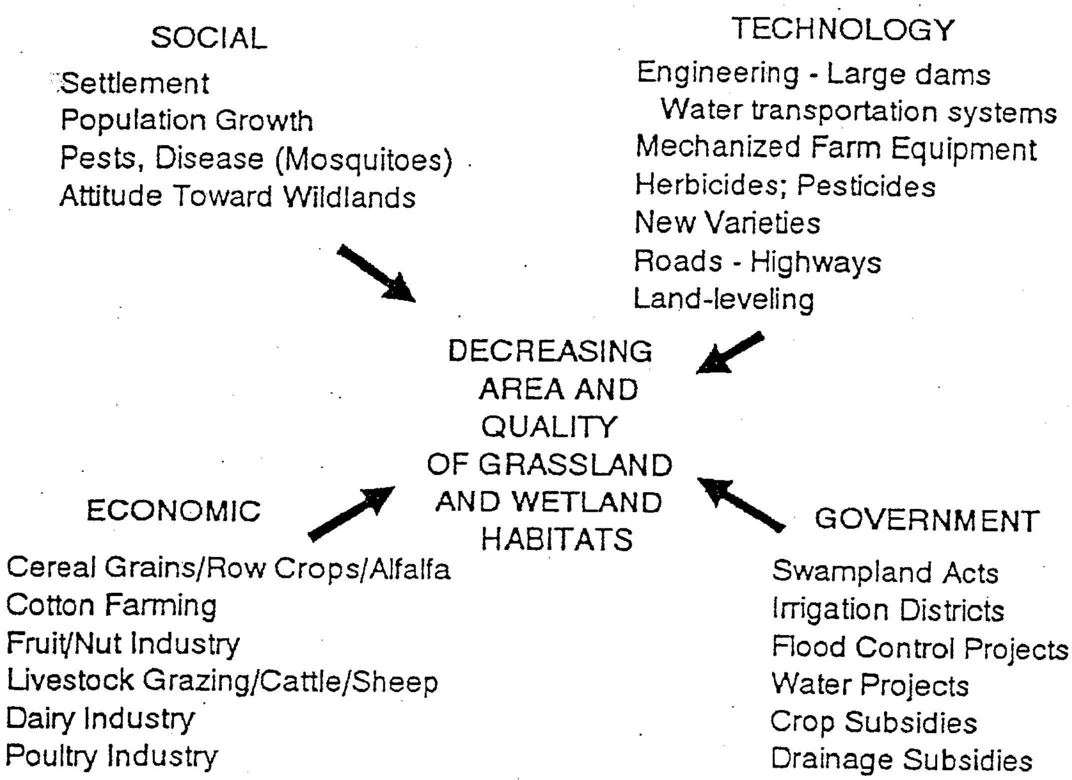

Fig. 24. Factors influencing the land-use and the amount and quality of native habitats in western Merced County.

wetland habitat that once was present in the Central Valley.

The challenge of providing habitat area requirements in the Grasslands is similar to the conditions surrounding urban areas across the U.S. Historically, disturbed sites were surrounded by large areas of native habitats. In contrast, current landscapes are characterized by small areas of remnant habitats in the midst of disrupted environments. Consequently, the importance of non-preserve lands or those not in public ownership is as important as parks and preserves for maintaining biodiversity and ecosystem functions (Norse et al. 1986, Wilcove 1988). In many cases, however, the combined land base remains small relative to the area requirements of all species composing an ecosystem. Thus, consideration must be given to the types of benefits that can be effectively and reliably provided for certain species, while realizing that efforts to assure the viability of certain populations will likely create conditions that will compromise the survival of others (Samson and Knopf 1983, Scott et al. 1991).

One of the greatest values of the Grassland study area is that it is the single largest block of wetland habitat remaining in the state of California and accounts for about one third of all wetlands remaining in the entire Central Valley. Furthermore, the Grasslands also represent the most important habitats remaining in the San Joaquin Valley, accounting for about 75% of the remaining wetland habitat. If this habitat were to diminish in size or be further degraded, the impacts would influence not only the local area but also have a profound impact on all the migratory species that use the Grasslands as a southern terminus during their annual cycle, exploit Grassland resources during their annual movements between their wintering and breeding grounds, or depend on these habitats for breeding.

CONTROL FRAGMENTATION

Even though the study area represents the largest remaining contiguous block of wetland habitat in the Central Valley, the existing habitat is highly fragmented. Every effort should be made to control any additional developments within the Grassland study area that will result in further fragmentation. Expansion of transportation corridors; development of new roads; construction of new electric transmission lines; and expansion of wastewater treatment facilities, golf courses, and urban areas are only a few examples of developments that contribute to a continuation of fragmentation. Foremost among the factors that determine the effects of fragmentation is the connectivity of biological processes (Noss 1991). Preserving the size of all remaining habitats is critical because as habitats are fragmented and isolated, biological processes are disrupted and interacting functional components of the larger system are degraded. Thus, the location and area of habitat impacted by such developments should be considered carefully in the planning process.

EXPANSION OF PUBLIC LANDS AND EASEMENTS

The importance of Grassland habitats to California, the Pacific Flyway, and the Nation should be used to justify the necessity of acquisition strategies to assure protection of all wetland types, develop reserves of adequate size to protect target populations, and promote the development of habitat corridors to link properties administered by state, private, and federal organizations. Expansion of state or federal ownership of key habitats and/or corridors important to maintaining wetland functions and values in the Grassland study area should continue.

Easements have been and will continue to be a valuable tool for protecting the Grasslands. The focus of current and historic easement efforts have been to secure a core area of wetland habitats. This strategy can be embellished in two ways. The first requires advanced planning to secure areas that connect existing habitats and insure the integrity of biological processes. The second strategy requires integrating programs and goals with the private sector to create a buffer zone of open lands surrounding the Grassland Wildlife Management Area. Developing such cooperative ventures with the private sector is the essence of the theme suggested by Morse et al. (1986) and Wilcove (1988). Careful planning allows private individuals to continue meeting economic objectives but within a framework that maximizes wetland and wildlife benefits.

RECOGNITION OF GRASSLAND HABITATS AS IMPORTANT RESERVES

The unique nature of the Grassland habitats are of sufficient significance that recognition of this area as a special reserve is worthy of investigation. The Ramsar Convention identifies wetlands of international importance. Efforts should be made to determine the feasibility for adding the Grasslands as a Ramsar Wetland. Identification of other programs that may contribute to increased recognition or protection of the Grassland region also should be explored.

AREA OF CRITICAL IMPORTANCE

The area of critical importance must be one that allows natural processes to continue with minimal interference and to prevent conflicting management from disrupting farm, commercial, urban, or wetland management. Protection of natural corridors and land surrounding the Grassland study area, prevention of additional hydrologic changes, and reducing management conflicts between different sectors within this core area are critical to maintaining system integrity. Clearly, protection of the core area of wetland habitats should continue as the focus of local easement and land protection programs. Promoting connectivity of habitats will increase the value of this program.

WETLAND MANAGEMENT

The development of agriculture was the primary reason for the loss and conversion of wetland habitats in the Grassland Study Area. Nationwide, intensive management on federal, state, and private wetlands has been recognized as providing important habitats for wetland wildlife (Kadlec and Smith 1992, Kaminski and Weller 1992). Although current wetland distribution differs from historic conditions, modern landscapes are dominated by a different proportion of wetland types and current functions and values are different from pristine conditions. Existing wetlands are critical for wetland wildlife within Merced County and in the Pacific Flyway. Although management activities can be disruptive to hydrological regimes or provide benefits for some species while compromising conditions for other species, the strategies used in intensive management are necessary to maintaining values and functions that relate to biodiversity (Fredrickson and Reid 1986, 1990, Laubhan and Fredrickson 1993, Fredrickson and Laubhan 1994b). As new opportunities with additional lands and programs are implemented, as new information is generated, and as the status of plant and animal species change, changes must be made in the strategies used in wetland management (Fig. 25). Management of every site in North America likely can be improved and the Grasslands are no exception. The judicious development and modification of wetlands, the use of substrate manipulations, and the effective use of water in intensive wetland management are all part of the bigger picture to maintain the functions and values of remnant wetlands. These actions must be well planned and implemented to maximize the potential of this important remnant wetland complex in the San Joaquin Valley.

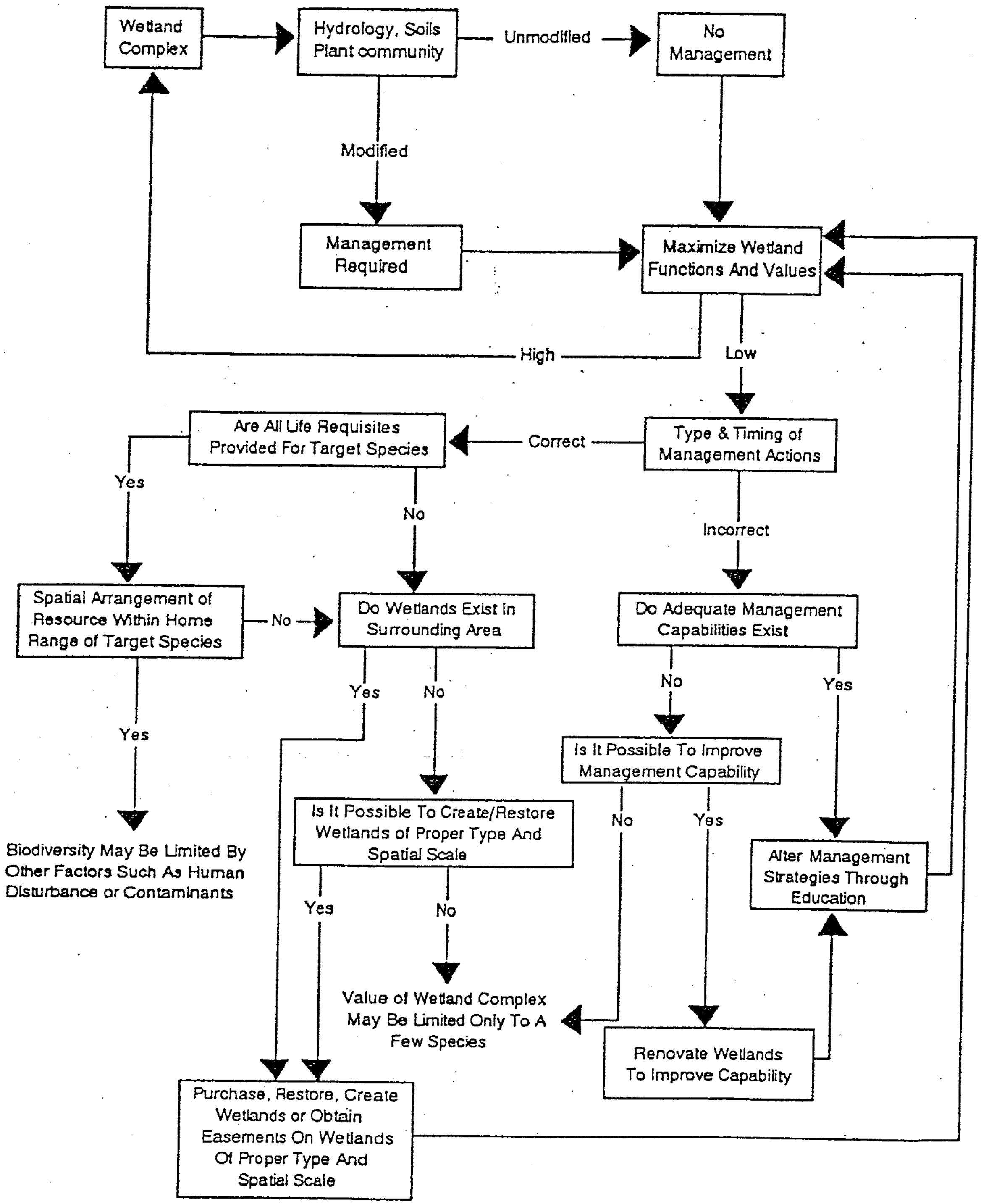

Fig. 25. Considerations required to make wise management decisions in man-modified landscapes.

LITERATURE CITED

Abbott Laboratories. 1992. VectoBac 12AS: Biological Larricide Aqueous Suspension, Abbott Laboratories, North Chicago, IL. 4pp.

Adams, L. W. and L. E. Dove. 1989. Wildlife reserves and corridors in the urban environment. U.S. Dep. Int., U.S. Fish and Wildl. Serv., Washington, DC. 91pp.

Alisaukas, R. T. and C. D. Ankney. 1992. The cost of egg laying and its relationship to nutrient reserves in waterfowl. Pages 30-61 *in* Batt, B. D. J., A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds., Ecology and Management of Breeding Waterfowl. Univ. Minnesota Press, Minneapolis.

_____, and _____. 1994. Nutrition of breeding female ruddy ducks: The role of nutrient reserves. Condor 96:878-897.

Aly, C. 1983. Feeding behavior of Aedes vexans larva (Diptera: Culicidae) and its influence on the effectiveness of *Bacillus thuringiensis* var. *israelensis*. Bull. Soc. Vector Ecol. 8:94-100.

Arkley, R. J. 1990. Soil survey of Merced Area, California, U.S. Dep. Agric. Soil Cons. Serv. U.S. Government Printing Office. 131pp.

Association of Bay Area Governments. 1991. Status and Trends Report on Land Use and Population: The geomorphology, climate, land use and population patterns in the San Francisco Bay. Delta and Central Valley Drainage Basins, Association of Bay Governments, Oakland, CA. 186pp.

Balling, S. S., T. Stoehr, and V. H. Resh. 1980. The effects of mosquito control recirculation ditches on the fish community of a San Francisco Bay salt marsh. Calif. Dep. Fish and Game. 66:25-34.

Barry, W. J. 1972. The Central valley prairie. Calif. Dept. Parks and Recreation. Sacramento. 82pp.

Batema, D. L., G. S. Henderson. and L. H. Fredrickson. 1985. Wetland invertebrate distribution in bottomland hardwoods as influenced by forest type and flooding regime. Proc. Central Hardwoods Forest Conf. 5:196-202.

Beck, A. M. 1973. The ecology of strategies and study of free ranging urban animals. York Press, Baltimore, MD. 98pp.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, PA and Wildlife Management Institute, Washington, DC. 544pp.

Blockstein, D. E. 1989. Toward a federal plan for biological diversity. Issues in Science and Technology 5:63–67.

Brennan, K. M. 1985. Effects of wastewater in wetland animal communities. Pages 199-222 in Godfrey, P. J., E. R. Kaymor, S. Pelczarski, and J. Benforado. Ecological considerations in wetlands treatment of municipal wastewater. Van Nostrand Reinhold Co., NY.

Brown, M. T., J. M. Schaefer and K. H. Brant. 1990. Buffer zones for water, wetlands and wildlife in East Central Florida. Final rep. (Fla. Agric. Exp. Sta. J. Ser. No. T-00061) to the East Central Fla. Reg. Plan. Council., Winter Park. 71+pp.

Brown and Caldwell Consulting Engineers. 1989. Report to City of Los Banos on the sewage disposal system expansion.

Buckley, C. E. 1989. The nutritional quality of selected rowcrop and moist-soil seeds for Canada geese. MS Thesis. University of Missouri-Columbia. 69pp.

Burcham, L. T. 1957. California range land. Calif. Forestry, Sacramento. 261pp.

Burney, D. A. 1993. Recent animal extinctions: Recipes for disaster. American Scientist 81:530-541.

Caldwell, L. K. 1993. The Ecosystem as a Criterion for Land Policy. Pages 103-208 in Caldwell, L. K. and K. Shrader-Frechette. eds. Policy for Land: Law and Ethics. Rowman and Littlefield Publishers, Inc. Lanham, MD.

California Department of Fish and Game. 1983. A plan for protecting, enhancing, and increasing California's wetlands for waterfowl. California Dept. Fish and Game, Sacramento. 53pp.

California Department of Fish and Game. 1991. 1990 annual report on the status of California's state listed, threatened and endangered plants and animals. State of California. The Resource Agency, Dep. Fish Game, Sacramento. 199pp.

Canadian Wildlife Service and U.S. Fish and Wildlife Service. 1986. North American Waterfowl Management Plan. Environmental Canada and U.S. Dep. Int., Washington, DC. 33pp.

Carson, W. P. and G. W. Barrett. 1988. Succession in old-field plant communities: effects of contrasting types of nutrient enrichment. Ecology 69:984-994.

Central Valley Joint Venture. 1990. Central Valley Habitat Joint Venture Implementation Plan: A component of the North American Waterfowl Management Plan. U.S. Fish and Wildl. Serv. 102pp.

Chadwick, D. H. 1991. Introduction in landscape linkages and biodiversity. Pages xv-xxvi *in* W. E. Hudson, ed. Landscape linkages and biodiversity. Island Press. Washington D.C.

Charbonneau, C.S., R. D. Drobney and C. F. Rabeni. 1994. Effects of *Bacillus thuringiensis* var. *israelensis* on nontarget benthic organisms in a lentic habitat and factors affecting the efficacy of the larvicide. Env. Toxicology and Chemistry 13:367-379.

Chasko, G. G. and J. E. Gates. 1982. Avian habitat suitability along a transmission line corridor in an oak-hickory forest region. Wildl. Monogr. 82:1-41.

Clark, T. W. and D. Zaunbrecher. 1987. The greater Yellowstone ecosystem: the ecosystem concept in natural resource policy and management. Renewable Resources J. 5:8-16.

Connelly, D. P. and D. L. Chesemore. 1980. Food habitats of pintails, *Anas acuta*, wintering on seasonally flooded wetlands in the northern San Joaquin Valley, California. Calif. Fish and Game 66:233-237.

Coombes, C. 1986. Current practice in controlling the effects of fresh water of urbanization in the Milton Keynes area.

Cooper, J. A., C. M. Potter, and C. H. Welling. 1989. Mallard duckling growth and behavior in methoprene treated wetlands. Final Report to Metropolitan Mosquito Control District, St. Paul, MN. 67pp.

Cooperrider, A. 1991. Conservation of Biodiversity on Western Rangelands Pages 40-53 *in* W. E. Hudson, ed. Landscape linkages and biodiversity. Island Press. Washington, DC.

Council on Environmental Quality. 1974. The costs of sprawling. Detailed Cost Analysis. U.S. Gov. Printing Office. Washington, DC. 278pp.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildl. Serv. Publ. FWS/OBS-79/31. 103pp.

Csuti, B. 1991. Introduction to Conserving Corridors: Countering habitat fragmentation. Pages 81-90 *in* W. E. Hudson, ed. Landscape linkages and biodiversity. Island Press. Washington D.C.

Cutler, M. R. 1991. Foreword in Landscape linkages and biodiversity. Pages ix-x *in* W. E. Hudson, ed. Landscape linkages and biodiversity. Island Press. Washington D.C.

Dahl, T. E. 1990. Wetland losses in the United States 1780's to 1980's. U. S. Fish and Wildlife Serv. Washington DC. 13pp.

Dahl, T. E. and C. E. Johnson. 1991. Status and trends of wetlands in the conterminous United States, mid-1970's to mid-1980's. U.S. Fish and Wildl. Serv. Washington, DC. 28pp.

Day, A. M. 1949. North American Waterfowl. Stackpole Books, Harrisburg, PA. 363pp.

Department of Finance. 1993. Population projections by race/ethnicity for Caliornia and its counties, 1990-2040. Report 93 P-1. Demograhi-Research Unit, Sacramento. 12pp.

Drobney, R. D. 1980. Reproductive bioenergetics of wood ducks. Auk 97:480-490.

Eberhard, T. 1954. Food habitats of Pennsylvania house cats. J. Wildl. Manage. 18:284-286.

Elton, C. S. 1958. The ecology of invasions by animals and plants. London:Methuen.

Environmental Protection Agency. 1972. The use of pesticides in suburban homes and garden and their impact on the aquatic environment. EPA, Office of Water Programs, U.S. Gov. Printing Office, Washington, DC.

Environmental Protection Agency. 1977. Urban Runoff Treatment methods, Volume I - Nonstructural Wetland Treatment, Nat. Tech. Info. Serv., Springfield, VA. 121pp.

Erwin, T. L. 1988. The tropical forest canopy: the heart of biotic diversity. Pages 123–129 *in* E. O. Wilson, ed., Biodiversity. National Academy Press. Washington, DC.

Euliss, N. H., Jr. and G. Grodhaus. 1987. Management of midges and other invertebrates for waterfowl wintering in California. Calif. Fish and Game 73:242-247.

Euliss, N. H., Jr. and S. W. Harris. 1987. Feeding ecology of northern pintails and green-winged teal wintering in California. J. Wildl. Manage. 51:724-732.

Farghal, A. I. 1982. Effect of temperature on the effectiveness of *Bacillus thuringiensis* var. *israelensis* against *Culex pipiens molestus* Forsk larvae. Z. Angew. Entomol. 94:408-412.

Ferguson, B. 1978. Erosion and sedimentation control in site waste planning. J. Soil and Water Conserv. 33:167-172.

Frayer, W. E., T. J. Monahan, D. L. Bowden, and F. A. Graybill. 1983. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970. Dep. For. Wood Sci., Colorado State Univ. Ft. Collins. 32pp.

Frayer, W. E., D. D. Peters and H. R. Pywell. 1989. Wetlands of the California Central Valley; status and trends 1939 to mid-1980's. U.S. Fish and Wildl. Serv., Portland, OR. 28pp.

Fredrickson, L. H. and F. A. Reid. 1986. Wetland and riparian habitats: a nongame management overview. Pages 59-96 *in* J. B. Hale, L. B. Best, and R. L. Clawson, eds. Management of nongame wildlife in the Midwest: A developing art. North-Cent. Sect., The Wildl. Soc., Grand Rapids, MI.

Fredrickson, L. H. and F. A. Reid. 1988a. Invertebrate response to wetland management. U.S. Dept. Interior, Fish and Wildl. Serv., Fish and Wildlife Leaflet 13.3.1. 6pp.

Fredrickson, L. H. and F. A. Reid. 1988b. Waterfowl use of wetland complexes. Waterfowl Management Handbook. U.S. Dept. Interior, Fish and Wildl. Serv., Fish and Wildlife Leaflet 13.2.1, Washington, DC. 6pp.

Fredrickson, L. H., and M. E. Heitmeyer. 1989. Waterfowl use of forested wetalnds in the southern United States: an overview. Pages 307-323 *in* M. W. Weller, ed. Waterfowl in winter. Univ. of Minnesota Press, Minneapolis.

Fredrickson, L. H., M. K. Laubhan, and A. Strong. 1989. Sherman Island Wildlife Management Plan. California Dept. Water Resources. Sacramento. 56pp.

Fredrickson, L. H. and F. A. Reid. 1990. Impacts of hydrologic alteration on management of freshwater wetlands. Pages 71-90 in J. M. Sweeney, ed. Management of Dynamic Ecosystems. North-Cent. Sect., The Wildlife Soc., Springfield, IL.

Fredrickson, L. H. and M. E. Heitmeyer. 1991. Life history strategies and habitat needs of the Northern pintail. U.S. Dept. Interior, Fish and Wildl. Serv., Fish and Wildlife Leaflet 13.1.3. 8pp.

Fredrickson, L. H. and M. K. Laubhan. 1991. Feasibility Assessment and Interim Plan for Management of Twitchell Island as a Waterfowl Area. California Dept. Water Res., Sacramento. 20pp.

Fredrickson, L. H. and M. K. Laubhan. 1994a. Managing wetlands for wildlife. Pages 623-647 *in* Bookhout, T. A. (ed.), Research and Management Techniques for Wildlife and Habitats. The Wildl. Soc. Bethesda, MD.

Fredrickson, L. H. and M. K. Laubhan. 1994b. (in press). Intensive wetland management: A key to biodiversity. Trans. N. Am. Wildl. Nat. Resour. Conf. 59:555-565.

Friend, M. 1985. Wildlife health implications of sewage disposal in wetlands Pages 262-269 in Godfrey, P. J., E. R. Kaymor, S. Pelczarski, and J. Benforado. Ecological considerations in wetlands treatment of municipal wastewater. Van Nostrama Reinhold Co., NY.

Friend. M. 1989. Avian Cholera: A major new cause of waterfowl mortality. U.S. Dept. Interior. Fish and Wildl. Serv., Fish and Wildlife Leaflet 13.2.5. 6pp.

Froke, J. B. 1986. Managing wildlife and development on one suburban/wildlife edge in southern California Wildlife Conservation and New Residential Developments.

Garcia, R., D. Des Rochers, W. Tozer and J. McNamara. 1983. Evaluation of *Bacillus thuringiensis* var. *israelensis* serotype H-14 for mosquito control. Proceedings, California Mosquito and Vector Control Association, Fresno, CA. 51:25-30

Geiss, A. D. 1974. Effects of urbanization and type of urban development on bird populations. Pages 97-105 in Noyes, J. H. and D. R. Progulske, eds. A symposium on wildlife in an urbanizing environment. Planning and Resour. Dev. Ser. 28. Holdsworth Nat. Resour. Cent., Univ. of MA, Amherst.

Gilmer, D. S., M. R. Miller, R. D. Bauer, and J. R. LeDonne. 1982. California's Central Valley wintering waterfowl: concerns and challenges. Trans. N. Am. Wildl. and Nat. Resour. Conf. 47:441-452.

Godron, M. and R. T. T. Forman. 1983. Landscape modification and changing ecological characteristics. Pages 12–28 *in* Mooney, H. A. and M. Godron, eds., Disturbance and ecosystems. Berlin:Springer-Verlag.

Gunwald and Associates. 1988. The comprehensive plan for the City of Los Banos, California. Sacramento.

Harris, L. D. 1984. The fragmented forest. Univ. of Chicago Press, Chicago, IL.

Harris, L. D. and P. Frederick. 1990. The role of the Endangered Species Act in the conservation of biological diversity: an assessment. *In* Cairns, J., Jr., and T., Crawford, eds.. Integrated Environmental Management Chelsea, MI:Lewis.

Harris, L. D. and K. Atkins. 1991. Faunal movement corridors in Florida. Pages 117–134 *in* W. E. Hudson, ed. Landscape linkages and biodiversity. Island Press. Washington D.C.

Heady, H. F. 1972. Burning and the grasslands of California. Proc. Ann. Tall Timbers Fire Ecol. Conf. 12:97–107.

Healy, H. F. 1988. Valley Grassland Pages 491–514 *in* M. G. Barbour and J. Major, eds. Terrestrial vegetation of California. California Native Plant Societ. Spec. Publ. No. 9

Heitmeyer, M. E. 1989. Agricultural/wildlife enhancement in California. The Central Valley Habitat Joint Venture. Trans. N. Am. Wildl. Nat. Resour. Conf. 54:391-401.

Heitmeyer, M. E., D. P. Connelly, and R. L. Pederson. 1989. The Central, Imperial, and Coachella Valleys of California. pages 475-505 *in* Smith, L. M., R. L. Pederson, and R. M. Kaminski, eds. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock.

Hendry, G. W. 1931. The adobe brick as a historical source. Agric. Hist. 5:110–127.

Hoffman, R. D. and T. A. Bookhout. 1985. Metabolizable energy of seeds consumed by ducks in Lake Erie Marshes. Trans. N. Am. Wildl. Nat. Res. Conf. 50:557-565.

Hudson, P. 1938. Red grouse production and management in relation to tourism. In Moorlands: wildlife conservation, amenity and recreation, ed. by K. Hearn. Recreational Ecology Research Group Report 8:45-54.

Huff, F. A. 1977. Effects of the urban environment on heavy rainfall distribution. Water Resources Bulletin. 13:807-816.

Hutto, R. L., S. Reel. and P. B. Londres. 1987. A critical evaluation of the species approach to biological conservation endangered species update 4:1–4.

Janzen, D. 1986. The eternal threat. Pages 286–303 *in* Soule, M. E., ed., Conservation biology: the science of scarcity and diversity Sunderland, MA:Sinauer.

Jean Hopkins and Associates, Inc. 1992. A biological framework for the protection of natural lands and endangered species in the southern San Joaquin Valley. San Joaquin Valley Bioregional Planning Biological Technical Committee. 27pp.

Johnson, W. C., R. K. Schreibar, and R. L. Burgess. 1979. Diversity of small mammals in a powerline right-of-way and adjacent forest in east Tennessee. Am. Midl. Nat. 101:231–235.

Kadlec, J. A. and L. M. Smith. 1992. Habitat management for breeding areas. Pages 590-610 *in* Batt, B. D. J., A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds., Ecology and Management of Breeding Waterfowl. Univ. Minnesota Press, Minneapolis.

Kam, J. T., T J. Grizzard, C. W. Randall and R. C. Hoehn. 1978. Urban runoff and the stream life of Occuguan. Pages 155-166 *in* The Freshwater Potomac: aquatic communities and environmental stresses. U.S. Dep. Int., U.S. Fish and Wildl. Serv.

Kaminski, R. M. and M. W. Weller. 1992. Breeding habitats of Nearctic waterfowl. Pages 568-589 *in* Batt, B. D. J., A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds., Ecology and Management of Breeding Waterfowl. Univ. Minnesota Press, Minneapolis.

Kjelmyr, J., G. W. Page, W. D. Shuford, and L. E. Stenzel. 1991. Shorebird numbers in wetlands of the Pacific Flyway: A summary of spring, fall, and winter counts in 1988, 1989, and 1990. Point Reyes Bird Observatory. 43pp.

Korschgen, C. E. and R. B. Dahlgren. 1992. Human disturbance of waterfowl: Causes, effects, and management. U.S. Dept. Interior, Fish and Wildl. Serv., Fish and Wildlife Leaflet 13.2.15. 8pp.

Kozlik, F. M. 1975. Management and production - west coast habitat. Proc. Int. Waterfowl Symp. 1:88-91.

Krapu, G. L. and K. J. Reinecke. 1992. Foraging ecology and nutritition. Pages 1-29 *in* Batt, B. D. J., A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds., Ecology and Management of Breeding Waterfowl. Univ. Minnesota Press, Minneapolis.

Kreig, A. and G. A. Langenbruch. 1981. Susceptibility of arthropod species to *Bacillus thuringiensis*. Pages 837-896 *in* H.D. Burges, ed., Microbial Control of Pests and Plant Diseases 1970-1980. Academic, New York, NY.

Laubhan, M. K. and L. H. Fredrickson. 1993. Integrated wetland management: concepts and opportunities. Trans. N. Am. Wildl. Nat. Resour. Conf. 58:323-334.

Leach, H. R. 1962. Grasslands Water District. Pages 44-45 *in* Casey, J. P. (ed.), The Grasslands Water Summary, Grassland Water District, Los Banos, CA.

Leach, H. R. 1960. Wildlife and fishery resources in relation to drainage disposal problems in the San Joaquin Valley, Calif. Dept. Fish and Game Final Rep. 127pp.

Levine, M. B., A. T. Hall. G. W. Barrett, and D. H. Taylor. 1989. Heavy metal concentrations during ten years of sludge treatment to an old-field community. J. Environ. Qual. 18:411–418.

Liddle, M. J. 1975. A selective review of the ecological effects of human trampling on natural systems. Biol. Conserv. 7:17-36.

Liddle, M. J. and H. R. A. Scorgie. 1980. The effects of recreation on freshwater plants and animals: a review. Biol. Conserv. 17:183-206.

MacArthur, R. H. and E. O. Wilson. 1967. The theory of island biogeography. Princeton Univ. Press. Princeton.

McMurry, F. B. and C. C. Sperry 1941. Food of female house cats in Oklahoma; a progress report. J. Mammology 22:185-190.

McNaughton, S. J. 1968. Structure and function in California grasslands. Ecology 49:962-972.

Maddox, J. V. 1975. Use of diseases in pest management. Pages 189-233 *in* R. L. Metcalf and W. H. Luckmann, eds., Introduction to Insect Pest Management. John Wiley & Sons, New York, NY.

Madsen, J. 1985. Impact of disturbance of field utilization on Pink-footed geese in West Jutland, Denmark. Biol. Conservation 33:53-63.

Magee, P. A. 1993. Detrital accumulation and processing in wetlands. U. S. Dept. Interior, Fish and Wildl. Serv., Fish and Wildlife Leaflet 13.3.14., Washington, DC. 7pp.

Maya, J. A. 1967. Vehicular pollution effects in urban development. J. Urban Planning and Develop. Div. 93(No. UP4):231-241.

Merced County Association of Governments. 1990. City of Dos Palos, Draft General Plan. 146pp.

Merced County Association of Governments. 1992. City of Gustine, General Plan. 170pp.

Merced County Planning Dept. 1990. Merced County, Year 2000 General Plan. Merced.

Merced Data Special Services, Inc. 1993. Maps prepared from a data base with GIS technology.

Merritt, R. W., K. W. Cummins, and T. M. Borton. 1984. The role of aquatic insects in the processing and cycling of nutrients. Pages 134-163 *in* Resh, V. C. and D. M. Rosenberg, eds. The ecology of aquatic insects. Praeger, NY.

Miller, M. R. 1987. Fall and winter foods of Northern pintails in the Sacramento Valley, California. J. Wildl. Manage. 51:405-414.

Minshall, G. W. 1984. Aquatic insect substratum relationships. Pages 358-400 *in*

Resh, V. C. and D. M. Rosenberg, eds. The ecology of aquatic insects. Praeger, NY.

Mitsch, W. J. and J. G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold, NY. 722pp.

Mooney, H. A. and J. Drake (eds.). 1986. The ecology of biological invasions of North America and Hawaii. New York:Springer-Verlag. pp.

Moore, J. W. 1980. Factors influencing the composition, structure and density of a population of benthic invertebrates. Arch. Hydrobiol. 88:202-218.

Munz, P. A. and D. D. Keck. 1959. A California flora. Univ. Calif. Press. Berkeley. 1681pp.

Murphy, D. D. 1988. Challenges to biological diversity in urban areas. Pages 71-82 in Wilson, F. O. and F. M. Peter (eds.). Biodiversity. National Academy Press, Washington, DC.

Nazar, P. G. 1990. Soil survey of Merced County, California, Western Part. U.S. Dept. Agric. Soil Cons. Serv., U.S. Government Printing Office. 468pp.

Norse, E., K. Rosenbaum, D. Wilcove, B. Wilcox, W. Romme, D. Johnston, and M. Stout. 1986. Conserving biological diversity in our national forests. Washington: Wilderness Society. North American. 1969.

Norton, B. 1988. Commodity, amenity, and mortality: the limits of quantification in valuing biodiversity. Pages 200–205 *in* E. O. Wilson, ed., Biodiversity, National Academy Press, Washington.

Noss, R. F. and L. D. Harris. 1986. Nodes, networks, and MUMs: preserving diversity at all scales. Environ. Management 10:299- 309.

Noss, R. F. 1987a. Corridors in real landscapes: a reply to Simberloff and Cox. Conserv. Biol. 1:159–164.

Noss, R. F. 1987b. From plant communities to landscapes in conservation inventories: a look at The Nature Conservancy (USA). Biol. Conserv. 41:11–37.

Noss, R. F. 1991. Landscape connectivity: Different functions at different scales. Pages 27–39 *in* W. E. Hudson, ed. Landscape linkages and biodiversity. Island Press. Washington D.C.

NRC - Committee on Irrigation-Induced Water Quality Problems. 1989.

Nudds, T. D. 1992. Patterns in breeding waterfowl communities. Pages 540-567 *in* Batt, B. D. J., A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds., Ecology and Management of Breeding Waterfowl. Univ. Minnesota Press, Minneapolis.

Odum, E. P. 1979. The value of wetlands: a hierarchial approach. Pages 16-25 in P. E. Greeson, J. R. Clark, and J. E. Clark, eds. Wetland functions and values: the state of our understanding. Am. Water Res. Assoc., Minneapolis, MN.

Ogden, G. R. 1988. Agricultural land use and wildlife in the San Joaquin Valley, 1769-1930: An overview. San Joaquin Valley Drainage Program, Sacramento, CA. 163pp.

Ogilvie, M. A. 1966. Population changes and mortality of Mute Swans in Britain. Wildfowl 18:64-73.

Owens, N. W. 1977. Responses of wintering brent geese to human distrubance. Wildfowl 28:5-14.

Owens, N. W. 1979. Responses of wintering Brent Geese to human disturbance. Wildfowl 28:5-14.

Owen, R. B., Jr., and K. J. Reinecke. 1979. Bioenergetics of breeding dabbling ducks. Pages 71-93 *in* Bookhout, T. A. (ed.). Waterfowl and Wetlands - an integrated review. Proc. Symp. North Central Sect. Wildl. Soc., Madison, WI.

Parmalee, P. W. 1953. Food habits of the female house cat in east-central Texas. J. Wildl. Manage. 17:375-376.

Raveling, D. G. and M. E. Heitmeyer. 1989. Relationships of population size and recruitment of pintails to habitat conditions and harvest. J. Wildl. Manage. 53:1088-1103.

Reid, F. A. 1985. Wetland invertebrates in relation to hydrology and water chemistry. Pages 72-79 *in* M. D. Knighten (ed.), Water impoundments for wildlife: A habitat management workshop. U.S. For. Serv., St. Paul, MN.

Samson, F. B. and F. L. Knopf. 1982. In search of a diversity ethic for wildlife management. Trans. N. Am. Wildl. and Nat. Resour. Conf. 47:421–431.

San Joaquin Valley Drainage Program. 1990. Fish and Wildlife Resources and Agriculture

Drainage in the San Joaquin Valley, California. Vol. 1, Sec. 2. 177pp.

Scott, J. M., B. Csuti, and S. Caicco. 1991. Gap Analysis: Assessing protection needs Pages 15–26 *in* W. E. Hudson, ed. Landscape linkages and biodiversity. Island Press. Washington D.C. 196pp.

Severson, D. J. 1987. Macroinvertebrate populations in seasonally flooded marshes in the San Joaquin Valley of California. MS. Thesis, Humboldt State Univ., Eureka, CA. 113pp.

Shaheen, D. G. 1975. Contributions of Urban Roadway Usage to water pollution. Office of Research and Development. U.S. EPA, Environ. Prot. Technology Series. EPA-60012-75-004. 228pp.

Shuford, W. D., G. W. Page and J. E. Kjelmyr. 1993. Distribution, abundance and habitat use of shorebirds in California's central valley in winter 1992-93. A report of Point Reyes Bird Observatory, Stinson Beach, CA. 17pp.

Soule, M. E. (ed.). 1987. Viable populations for conservation. Cambridge Univ. Press, Cambridge.

Soule, M. E. 1991. Theory and Strategy. Pages 91–104 *in* W. E. Hudson, ed. Landscape linkages and biodiversity. Island Press. Washington D.C.

Spalding, B. W. and F. O Heady. 1977. Future use of agricultural land for nonagricultural purposes. J. Soil and Water Conserv. 32:88-93.

State of California - The Resources Agency. 1988. California wetlands. California Dept. Parks and Rec., Sacramento. 32pp.

State of California. 1993. Population projections by race/ethnicity for California and its counties 1990-2040. Report 93 P-1, Demographic Research Unit, Department of Finance, Sacramento. 10pp.

Stebbins, G. L. 1965. Colonizing species of the native California flora. Pages 173–191 *in* H. G. Baker and G. L. Stebbins, eds. The genetics of colonizing species. Academic Press, New York.

Swanson, G. A. 1977. Diel food selection by Anatinae on a wastewater stabilization system. J. Wildl. Manage. 41:226-231.

Temple, S. A. and J. R. Cary. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conserv. Biol. 2:340–347.

Tiner, W. R., Jr. 1984. Wetlands of the United States: Current status and recent trends. U.S. Fish and Wildl. Serv., Washington, DC. 59pp.

Titche, A. R. 1979. Avian cholera in California. California Dept. of Fish and Game Report No. 79-2. 49pp.

Toner, G. C. 1956. House cat predation on small mammals. J. Mammology 37:119.

Uhler, F. M. 1956. New habitats for waterfowl. Trans. N. Am. Wildl. Conf. 21:453-469.

U.S. Department of Agriculture. 1941. Climate and man. Yearbook of Agriculture. U.S. Government Printing Office. Washington, DC. 1247pp.

U.S. Department of the Interior. 1970. Storm water pollution from urban land activity. Federal Water Quality Administration. U.S. Gov. Printing Office, Washington, DC.

U.S. Department of the Interior and California Resources Agency. 1990. A management plan for agricultural subsurface drainage and related problems on the west side of the San Joaquin Valey. Final Report of the San Joaquin Valley Drainage Program. 183pp.

U.S. Fish and Wildlife Service. 1978. Concept plan for waterfowl wintering habitat preservation, Central Valley, California. U.S. Fish and Wildl. Serv., Region 1, Portland, OR. 116pp.

U.S. Fish and Wildlife Service. 1987. Draft Concept plan for waterfowl wintering habitat preservation - an update, Central Valley. U.S. Dept. Int., U.S. Fish and Wildl. Serv., Region 1, Portland, OR 17pp.

U.S. Fish and Wildlife Service. 1990. Endangered and Threatened Wildlife and Plants. U. S. Dep. Interior, U. S. Fish and Wildlife Service, 50 CFR 17.11 and 17.12, 36pp.

van der Zande, A. N., W. J. ter Keurs, and W. J. van der Weijden. 1980. Biol. Conserv. 18:299-321.

Voorhees, A. M. and Associates, Inc. 1971. A guide for reducing air pollution through urban planning. EPA Office of Air Programs, Washington, DC.

Walcott, C. F. 1974. Changes in bird life in Cambridge Massachusetts from 1860-1964. Auk 91:151-160.

Waller, D. M. 1991. Introduction to conserving biodiversity: A unified approach. Pages 3–13 *in* W. E. Hudson, ed. Landscape linkages and biodiversity. Island Press. Washington D.C. 196pp.

Warbash, O. 1958. Bird populations in relation to changes in land use. J. Wildl. Manage. 22:23-28.

Warner, R. E. and S. J. Brady. 1994. Managing farmlands for wildlife. Pages 648-662 *in* Bookhout, T. A. (ed.). Research and Management Techniques for Wildlife and Habitats. The Wildl. Soc. Bethesda, MD.

Weller, M. W. 1987. Freshwater Marshes. Univ. Minnesota Press, Minneapolis. 2nd Edition. 150pp.

Whitney, S. W. 1979. The Sierra Nevada. Sierra Club Books. San Francisco, CA. 526pp.

Wilcove, D. S. 1987. From fragmentation to extinction. Nat. Areas J. 7:23–29.

Wilcove, D. S. 1988. National forests: policies for the future. Vol. 2: Protecting biological diversity. Washington:Wilderness Society.

Wilcove, D. S., C. H. McLellan, and A. P. Dobson. 1986. Habitat fragmentation in the temperate zone. Pages 237–256 *in* Soule, M. E. ed., Conservation Biology: the science of scarcity and diversity. Sunderland, MA:Sinauer.

Wilcox, B. A. and D. D. Murphy. 1985. Conservation strategy: the effects of fragmentation on extinction. Am. Naturalist 125:879- 887.

Wilhelm, M., S. R. Lawry, and D. D. Hardy. 1989. Creation and management of wetlands using municipal wastewater in northern Arizona: a status report. Pages 179-185 in Hammer, D. A. (ed.), Constructed Wetlands for Wastewater Treatment. Lewis Publishers, Chelsea, MI.

Wilson, E. O. 1987. The little things that run the world (the importance and conservation of invertebrates). Conserv. Biol. 1:344–346.

Wilson, E. O. 1988. The current state of biological diversity. Pages 3-18 *in* Wilson, E. O. ed., Biodiversity. National Academy Press. Washington.

Winton, J. M. 1962. Grassland Water Page 42 *in* Casey, J. P. ed., The Grasslands Water Summary. Grassland Water District. Los Banos, CA.

Wraight, S. P., D. Molloy, H. Jamnback and P. McCoy. 1981. Effects of temperature and instar on the efficacy of *Bacillus thuringiensis* var. *israelensis* and *Bacillus sphaericus* strain 1593 against *Aedess stimulans* larvae. J. Invert. Pathol. 38:78-87.

Wright, J. W., ed. 1993. The Universal Almanac. Andrews and McNeel, Kansas City, MO. 714pp.

Yalden, P. E. and D. W. Yalden. 1988. The level of recreational pressure on Blanket Bog in the Peak District National Park, England. Biological Conservation 44:213-227.

Zoecon. 1990. Altosid Liquid Larvicide Concentrate. Zoecon Corporation, Dallas, TX. 4pp.

APPENDIX 1. SCIENTIFIC NAMES OF BIRDS NOT APPEARING IN THE TEXT

Pied-billed grebe, *Pdilymbus podiceps*
Western grebe, *Aechmophorus occidentalis*
American bittern, *Botaurus lentiginosa*
Great egret, *Casmerodius albus*
Snowy egret, *Egretta thula*
Green-winged teal, *Anas crecca*
Blue-winged teal, *Anas discors*
Northern shoveler, *Anas clypeata*
American wigeon, *Anas americana*
Canvasback, *Aythya valisneria*
Ring-necked duck, *Aythya collaris*
Turkey vulture, *Cathartes aura*
White-tailed kite, *Elanus caeruleus*
Red-shouldered hawk, *Buteo lineatus*
Red-tailed hawk, *Buteo jamaicensis*
Rough-legged hawk, *Buteo lagopus*
American kestrel, *Falco aparvirius*
Ring-necked pheasant, *Phasinus colchicus*
California quail, *Callipepla californica*
Coot, *Fulica americana*
Lesser sandhill, *Grus canadensis*
Black-bellied plover, *Pluvialis squatarola*
Semi-palmated plover, *Charadrius semipalmatus*
Greater yellowlegs, *Tringa melanoleuca*
Lesser yellowlegs, *Tringa flavipes*
Solitary sandpiper, *Tringa solitaria*
Willet, *Cataptrophorus semipalmatus*
Spotted sandpiper, *Actitis macularia*
Whimbrel, *Numenius phaepus*
Marbled godwit, *Limosa fedoa*
Sanderling, *Calidris alba*
Western sandpiper, *Calidris mauri*
Least sandpiper, *Calidris minutilla*
Dunlin, *Calidris alpina*
Ruff, *Philomachus pugnax*
Dowitcher, *Limnodromus spp.*
Common snipe, *Gallinago gallinago*
Red-necked phalarope, *Phalaropus lobatus*
Ring-billed gull, *Larus delawarensis*
California gull, *Larus californicus*
Mourning dove, *Zenaida macroura*
Great-horned owl, *Bubo virginianus*
European starling, *Sturnus vulgaris*
Red-winged blackbird, *Agelaius phoeniceus*
Yellow-headed blackbird, *Xanthocephalus xanthocephalus*
Brewer's blackbird, *Euphagus cyanocephalus*

EXHIBIT 12

Korschgen, C.E. and Dahlgren, R.B., U.S. Fish and Wildlife Service, Fish and Wildlife Leaflet 13.2.15, "Human Disturbances of Waterfowl: Causes, Effects, and Management

13.2.15. Human Disturbances of Waterfowl: Causes, Effects, and Management

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Human disturbances of waterfowl can be intentional or unintentional. They may result from overt or directed activities or may be ancillary to activities not initially thought to be of concern to birds. Some of these disturbances are manifested by alertness, fright (obvious or inapparent), flight, swimming, disablement, or death. Therefore, persons responsible for waterfowl management areas should be aware of the problems from human disturbance and should design management and facilities that increase public appreciation of waterfowl.

In the last 20 years, the intensity of water-based recreation increased drastically, especially on inland waters. Waterfowl are wary, seeking refuge from all forms of disturbance, particularly those associated with loud noise and rapid movement. Occasionally, the problem of human disturbance of waterfowl resulted in formal litigation. In Nevada, for example, the Refuge Recreation Act of 1962 was affirmed to permit recreational use only when it did not interfere with the primary purpose for which the Ruby Lake National Wildlife Refuge was established. Compatibility of an activity is based on site-specific effects on the major purposes for which a refuge was established. In a recent survey of harmful and incompatible uses on national wildlife refuges, 42 use categories were determined that could be potential disturbances of waterfowl.

Activities That Cause Disturbances

Given the frequency of human disturbance of waterfowl, information from research about this issue is scant. A review of several thousand journal articles and books revealed that most disturbances are created by water users (chiefly boaters, anglers, hunters) and aircraft (Table). Human activities cause different degrees of disturbance to waterfowl and may be grouped into four main categories. Listed in order of decreasing disturbance these categories are

1. rapid overwater movement and loud noise (power-boating, water skiing, aircraft);
2. overwater movement with little noise (sailing, wind surfing, rowing, canoeing);

3. little overwater movement or noise (wading, swimming); and
4. activities along shorelines (fishing, bird-watching, hiking, and traffic).

Disturbances displaced waterfowl from feeding grounds, increased energetic costs associated with flight, and may have lowered productivity of nesting or brooding waterfowl. Many authors either directly or indirectly implicated themselves as a cause of disturbance during their studies of waterfowl.

Effects on Breeding Waterfowl

Annual increases in waterfowl numbers are determined by several components of reproduction, including the number of breeding pairs, hatching success, and survival of the young. Human disturbance can reduce several of these components, and, in time, result in a declining waterfowl population.

Declining Numbers of Breeding Pairs

Disturbances during critical times of the nesting cycle eventually cause ducks to nest elsewhere or not to nest at all. In Maine, American black ducks and ring-necked ducks did not nest under conditions of excessive human disturbance. Mallards at the Seney National Wildlife Refuge in Michigan failed to nest in areas open to fishing. Some Wisconsin lakes bordered by homes were so heavily used for recreation that breeding ducks did not use otherwise suitable habitat. In Germany, an 85% decrease of the breeding stock of ducks at two small ponds presumably was caused solely by disturbance from an increasing number of anglers during the waterfowl breeding season. Numbers of mallards, green-winged teals, northern shovelers, pochards, and tufted ducks decreased from 26 pairs to 4 pairs during an 8-year period. Human activity on islands can altogether discourage nesting in waterfowl.

Increased Desertion of Nests

Studies of several species of waterfowl identified human disturbances as the cause of desertions or abandonments of nests, especially during early incubation. Disturbance from observers caused a 10% nest abandonment rate by mallards using artificial nest baskets in an Iowa study. Frequent visits to goose nests by biologists

Table. *Human disturbances of waterfowl by source of disturbance, effect, and number of citations in 211 journal articles on the subject.*

Subject	Number of citations
Sources of Disturbance (in alphabetic order)	
Aircraft	
Airplanes	15
Helicopters	10
General	22
Anglers (see fishing)	
Baiting/artificial feeding	7
Barges/shipping	9
Boating (boats, canoes, rowing, airboats, sailing)	66
Cats	2
Development (industrial, pollution, urban, construction)	24
Dogs	6
Farming	19
Fishing	
Commercial	5
Sport (angling)	50
Hazing (scaring)	12
Human activity/disturbance, general	58
Hunting	
Sport	71
Subsistence	2
Military	5
Noise	22
Recreation	
General	18
Aquatic	27
Research/investigator	55
Roads	
General	10
Traffic	11
Trains	1
Trapping	
Furbearer	1
Waterfowl	5
Effects (in alphabetical order)	
Breeding chronology interrupted	2
Brood breakup	14
Brood rearing disrupted	7
Energetic cost (flight) increased	23
Family breakup	6
Feeding interrupted or decreased	52
Molting birds harrassed	9
Nest/nesting	
nest disturbed by researchers	55
nest disturbed by others	27
nesting success reduced	14
Predation on clutches and chicks increased because of research	31
Wariness (alertness, tolerance distance) increased	43

caused nest desertion rates as high as 40%. Canada geese nesting in southeastern Missouri were very sensitive to persons fishing in their nesting areas. Establishing areas closed to fishing during the nesting period decreased nest desertions.

Reduced Hatching Success

Human disturbance has three basic effects on nesting success, that is:

1. exposure of eggs to heat or cold by flushing of hens may kill the embryos;
2. predation of eggs may increase when hens are flushed from nests; and
3. predation of eggs and hens may increase at nests when humans create trails or leave markers by which predators find nests.

When nests of cackling Canada geese were checked several times before hatch, twice the number of eggs were lost to predators. Where human activities disturbed Canada geese or common eiders that were nesting among black-backed gulls, herring gulls, or parasitic jaegers on islands or tundra colonies, the gulls and jaegers often quickly located and consumed eggs in waterfowl nests unoccupied because of human disturbance.

Decreased Duckling Survival

Disturbance by humans during the brood rearing season can break up and scatter broods or frighten parents into running ahead of their ducklings or goslings. Young waterfowl briefly separated from their mother are vulnerable to predators and susceptible to death from severe weather or lack of experience in obtaining food. Disturbances drastically increase kills by gulls of common eider ducklings. For example, the number of eider ducklings killed by gulls in Sweden was 200–300 times greater when broods were disturbed by boats. In northern Maine, American black duck and ring-necked duck broods averaged two fewer ducklings because of mortality from disturbance by motorboats. Human disturbance caused a higher than normal mortality rate of trumpeter swan cygnets in a study area in Alaska. Human disturbance can be quite brutal and direct; water skiers and power boaters have run over white-winged scoter hens and broods, and some boaters have used paddles to kill ducklings.

Effects on Nonbreeding Waterfowl

Migratory and wintering waterfowl generally attempt to minimize time spent in flight and maximize time for feeding. Flight requires considerably more energy than any other activity, except egg laying. Human disturbance compels waterfowl to change food habits, feed only at night, lose weight, or desert the feeding area. Waterfowl respond both to loud noises and rapid movements, such as boats powered by outboard motors, and to visible features, such as sailing boats. Large flocks of waterfowl are more susceptible to disturbances than small flocks.

Not all waterfowl species are equally sensitive to disturbance, and some may habituate to certain disturbances. Pink-footed geese were disturbed at a distance of 500 m when more than 20 cars per day used a road in the fall. Traffic of as few as 10 cars per day also had a depressing effect on habitat use by geese. Thus, the surrounding buffer area must exceed 500 m to render habitat acceptable to flocks of pink-footed geese. Some waterfowl, especially diving ducks (notably canvasbacks and lesser scaups) and geese (notably brants and snow geese) are especially vulnerable to disturbance. Density and pattern of disturbance may influence diving ducks more than dabbling ducks in most areas. Repeated disturbances also can deny birds access to preferred feeding habitats. Use by diving ducks of several good feeding areas along the Upper Mississippi River has been limited primarily by boating disturbances that cause 90 percent of the waterfowl to concentrate on 28 percent of the study area during daytime.

Increased Energy Expenditure and Depleted Fat Reserves

In the absence of disturbance, brants in Great Britain spent an average of 1.1% of their time in flight, but disturbance on weekends caused the time spent in flight to increase as much as sevenfold and prevented brants from feeding for up to 11.7% of the time. Detailed studies are few, but observations suggest that the effects of intensive recreation during the fall and winter could be deleterious to migrating and wintering waterfowl.

Researchers who attempted to quantify the harm from disturbances on migrating and wintering waterfowl indicated that frequency of disturbance, number of affected birds, and changes in behavior are greater than most suspected. For example, each duck and American coot on Houghton Lake, Michigan, was disturbed on the average of 1.5 times per weekday and more than 2 times during weekend days. On Navigation Pool 7 of the Upper Mississippi River, an average of 17.2 boats passed through the study area each day and resulted in 5.2 disturbances per day and a minimum of over 4 min of additional flight time per disturbance of waterfowl. Birds may have flown up to an additional hour each day because of human disturbances. Over 2500 tundra swans left their most important feeding area on the Upper Mississippi River in response to two small boats.

Changed Migration Patterns

Prolonged and extensive disturbances may cause large numbers of waterfowl to leave disturbed wetlands and migrate elsewhere. These movements can be local in areas of plentiful habitat or more distant and permanent in areas of sparse habitat, causing shifts in flyway migration patterns. Extensive disturbances on migration and wintering areas may limit the use by waterfowl below the carrying capacity of wetlands. Daily disturbance by boaters may have been responsible for eliminating the brant population that once spent November and December on Humboldt Bay, California.

Management Considerations

Fortunately, numbers of breeding waterfowl usually increase in response to reduction or elimination of human disturbances. For the benefit of waterfowl, the harm from human disturbances must be minimized or eliminated. Management alternatives that reduce human disturbances of waterfowl include:

1. increasing the quantity, quality, and distribution of foods to compensate for energetic costs from disturbances;
2. establishing screened buffer zones around important waterfowl roosting and feeding areas;
3. reducing the number of roads and access points to limit accessibility to habitats;
4. creating inviolate sanctuaries; and
5. reducing the sources of loud noises and rapid movements of vehicles and machines.

Disturbances occur chiefly during all critical parts of the annual cycle of waterfowl—nesting, brood rearing, migration, and wintering. Each part of the cycle is crucial to the breeding and survival of waterfowl populations. Common to all parts of the cycle is disturbance while feeding, which may increase flight time and decrease feeding time. Disturbances of nesting birds may cause abandonment of the nest, disruption of the pair bond, reduction in clutch size, increased egg mortality, abandonment of the nesting area, and increased predation of the nest. Disturbances during brood-rearing may cause exhaustion of young and an increase in losses from predation. These disturbances can be lessened or their effects mitigated on refuges or other areas managed for waterfowl. Because disturbances are sometimes caused by professional wildlife managers or researchers and private citizens, creation of sanctuaries is often necessary at critical times and locations. Access to roads and trails can be limited for professionals and for bird-watchers. Activities of other users of wildlife, such as trappers and hunters, may have to be restricted in space and time; boating, angling, camping, and picnicking may be restricted similarly. Human disturbance often is increased by viewing platforms and waterfowl can be viewed at a closer distance if the platform is screened with vegetation and made more like a blind. Proper screens and appropriate control of noise let people really enjoy wildlife close at hand.

Structures such as pumping stations and maintenance buildings on wildlife areas should be screened and placed where necessary human visits cause the least disturbance of waterfowl. Disturbances, particularly at critical times of the year, can be reduced notably by restricting access of pedestrians, autos, and boats; by regulating activities such as farming, grazing, bait collecting, camping, hunting, fishing, and trapping; and by prohibiting the use of nets that can entrap diving ducks. Access by dogs and other pets should not be permitted in critical areas during the nesting and brood-rearing periods. Airboats, aircraft, and all-terrain-vehicles are often useful to managers of waterfowl and wetland, but their use must be carefully planned to minimize harm from sight or sound. Construction of dikes, canals, water control structures, roads, and similar structures and military uses of wetlands or refuge areas should be scheduled for non-critical times in the annual activity cycle of waterfowl.

Disturbance of feeding waterfowl can sometimes be mitigated by acquiring feeding areas on privately owned land to create a sanctuary or by practicing moist soil management and thus increasing the availability of highly nutritious foods in the refuge or wetland areas. With careful planning, deleterious effects of human disturbance on waterfowl can be mitigated or eliminated by creating sanctuaries in time and space (Figs. 1 and 2).

Managers must aggressively protect waterfowl from any human disturbance that reduces productivity and health of populations. To accomplish this goal, managers must resolve conflicting interests between needs of the public and needs of wildlife and researchers must gather more data to provide a greater range of management options.

Suggested Reading

Åhlund, M., and F. Götmark. 1989. Gull predation on eider ducklings *Somateria mollissima*: effects of human disturbance. Biological Conservation 48:115-127.

Bélanger, L., and J. Bédard. 1989. Responses of staging snow geese to human disturbance. Journal of Wildlife Management 53:713-719.

Bouffard, S. H. 1982. Wildlife values versus human recreation: Ruby Lake National Wildlife Refuge. Transactions of the North American Wildlife and Natural Resources Conference 47:553-558.

Braun, C. E., K. W. Harmon, J. A. Jackson, and C. D. Littlefield. 1978. Management of National Wildlife Refuges in the United States: its impacts on birds. Wilson Bulletin 90:309-321.

Burger, J. 1981. The effect of human activity on birds at a coastal bay. Biological Conservation 21:231-241.

Dahlgren, R. B., and C. E. Korschgen. 1992. Human disturbance to waterfowl: an annotated bibliography. U.S. Fish and Wildlife Service Resource Publication 188. 62 pp.

Edington, J. M., and M. A. Edington. 1986. Ecology, recreation, and tourism. Cambridge University Press, New York. 198 pp.

Korschgen, C. E., L. S. George, and W. L. Green. 1985. Disturbance of diving ducks by boaters on a migrational staging area. Wildlife Society Bulletin 13:290-296.

Liddle, M. J., and H. R. A. Scorgie. 1980. The effects of recreation on freshwater plants and animals: a review. Biological Conservation 17:183-206.

Pomerantz, G. A., D. J. Decker, G. R. Goff, and K. G. Purdy. 1988. Assessing impact of recreation on wildlife: a classification scheme. Wildlife Society Bulletin 16:58-62.

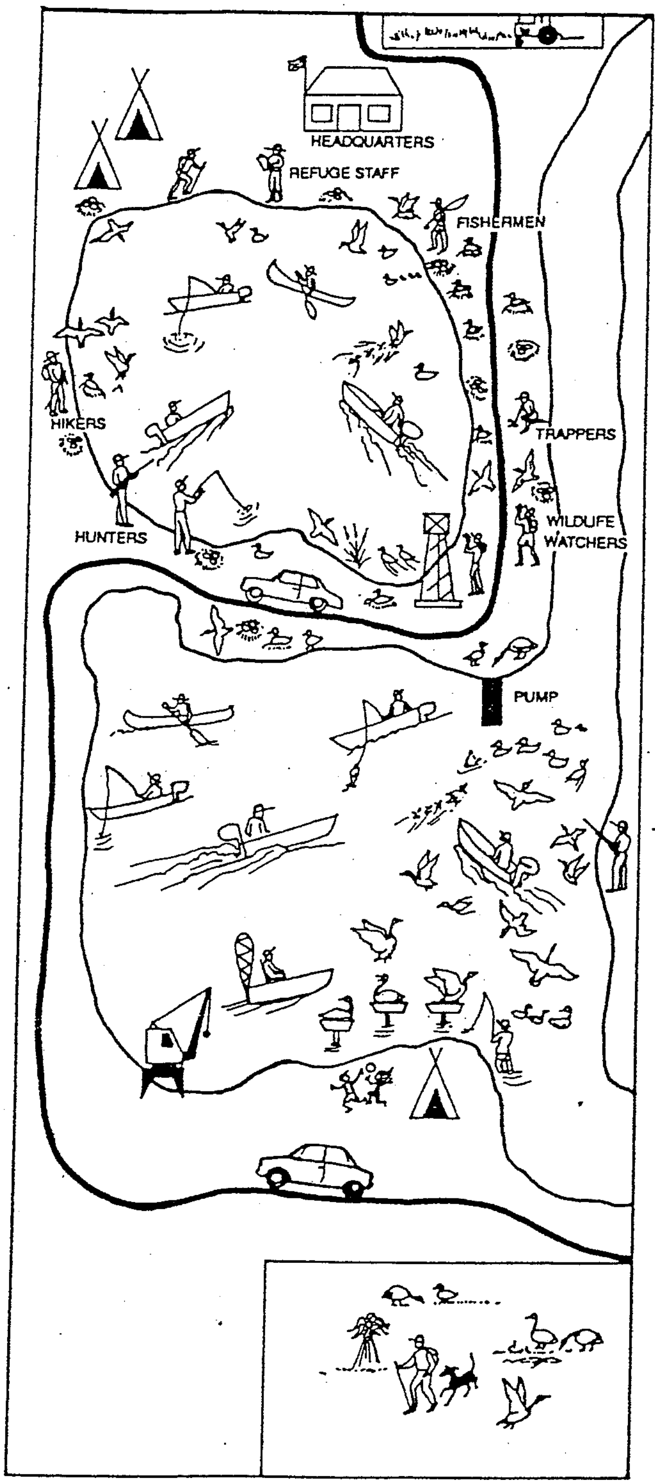


Fig. 1. Example of waterfowl refuge with excessive level of human disturbance of waterfowl.

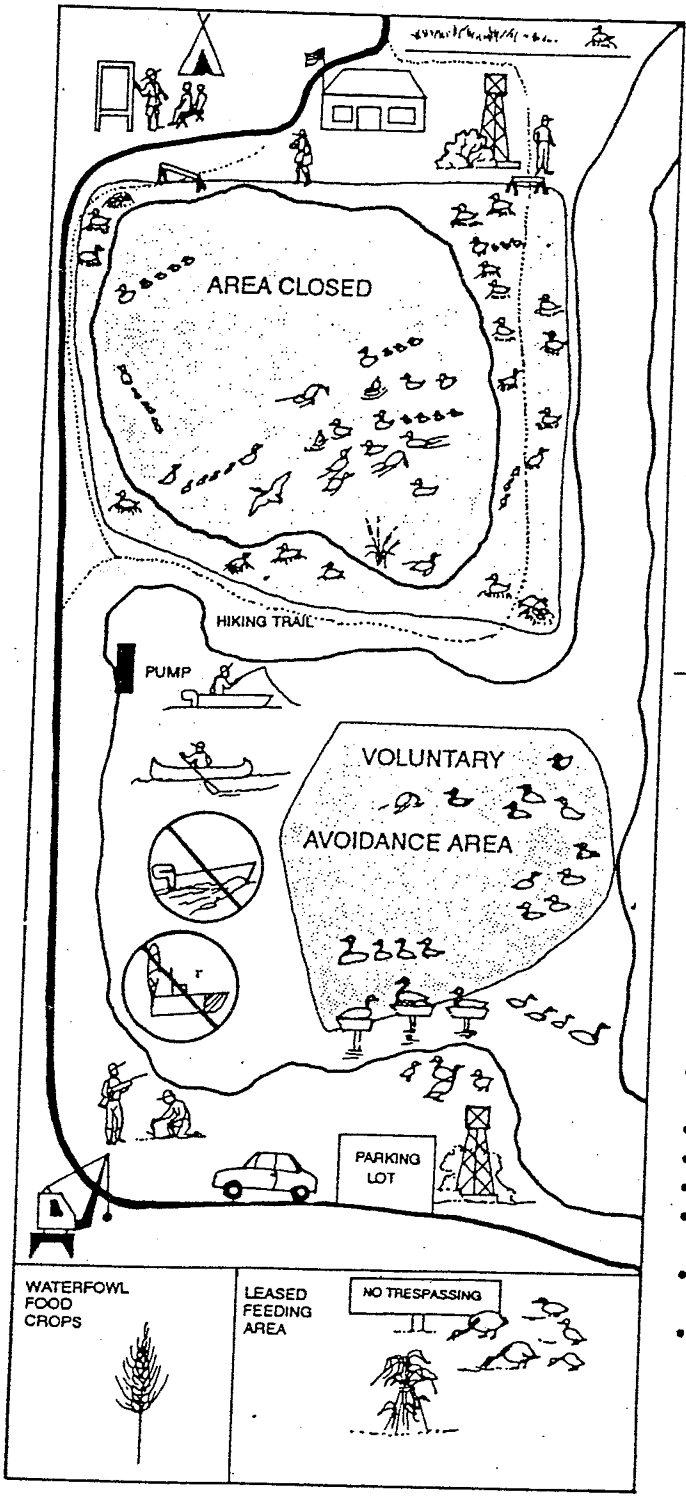
Spring and Summer

Ducks nest along dikes and in the uplands, and geese nest in tubs on end of lake. Fewer pairs are nesting each year, and many nests are abandoned or destroyed. Predation rates are high, especially in disturbed areas. Disturbance factors seem to be automobiles on tour routes, anglers on shores and in boats on the lake, hikers on trails, and users of the observation tower.

Females hatch large clutches, but survival of young is lower than expected.

Fall and winter

The lake is an important staging area for several species of diving ducks; large numbers of ducks and geese feed in the uplands on and around the refuge. Waterfowl numbers are decreasing despite favorable habitat. The frequency of human disturbance seems to have increased, especially from hunters, late season anglers and boaters, the auto tour, hikers, and wildlife watchers. It is also apparent that refuge staff are spending a lot of time working on minor projects.



Spring and summer

- Provide educational information so that the public knows the effects of disturbances on the predominant species.
- Seasonally close or restrict use of auto tour. Users of auto tour must stay in vehicles and stop in only designated parking areas.
- Seasonally close or restrict use of hiking and canoe trails.
- Close or restrict the fishing season during peak nesting period.
- Permit camping in only designated areas.
- Delay hay cutting until most clutches have hatched.
- Prioritize and limit special use permits.
- Limit access until most young waterfowl are three weeks old.

Fall and winter

- Provide educational information so that the public knows the migration and wintering requirements of the predominant species.
- Reroute auto tour to areas of secondary importance to waterfowl.
- Move or screen observation towers.
- Close selected areas of the refuge to public access.
- Create voluntary avoidance areas on federal and state waterways.
- Modify regulations to restrict disturbances from hunting and trapping.
- Move water pumping stations away from bird concentration areas.
- Raise high quality waterfowl foods on refuge land.
- Limit size and horsepower of boats on the lake.
- Disallow use of airboats.
- Obtain short term leases and prevent trespass on private lands that contain waste grain.
- Limit the time that refuge staff spend in high waterfowl use areas.
- Delay construction until non peak seasons.

Fig. 2. Examples of management practices that have reduced the level of human disturbance of waterfowl at a refuge.

Appendix. Common and Scientific Names of Birds Named in Text.

Ducks	
Northern shoveler	*Anas clypeata*
Green-winged teal	*Anas crecca*
Mallard	*Anas platyrhynchos*
American black duck	*Anas rubripes*
Lesser scaup	*Aythya affinis*
Ring-necked duck	*Aythya collaris*
Common pochard	*Aythya ferina*
Tufted duck	*Aythya fuligula*
Canvasback	*Aythya valisineria*
White-winged scoter	*Melanitta fusca*
Common eider	*Somateria mollissima*
Geese	
Pink-footed goose	*Anser brachyrhynchus*
Snow goose	*Anser caerulescens*
Brant	*Branta bernicla*
Canada goose	*Branta canadensis*
Cackling Canada goose	*Branta canadensis minima*
Swans	
Trumpeter swan	*Cygnus buccinator*
Tundra swan	*Cygnus columbianus*
Other	
American coot	*Fulica americana*
Herring gull	*Larus argentatus*
Great black-backed gull	*Larus marinus*
Parasitic jaeger	*Stercorarius parasiticus*

Note: Use of trade names does not imply U.S. Government endorsement of commercial products.

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Fish and Wildlife Leaflet 13
Washington, D.C. • 1992

EXHIBIT 13

Hostege, "Truth May Have Come off the Tracks," Oakland Tribune (August 22, 2004)

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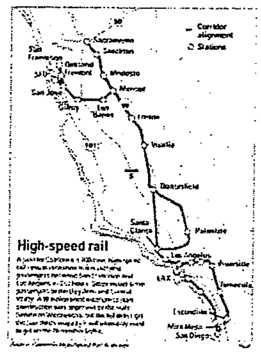
Article Last Updated: Sunday, August 22, 2004 - 5:43:07 AM PST

Truth may have come off the tracks



Rail Authority efforts leave some legislators questioning if proposed high-speed rail project is 'a fraud'

By Sean Holstege, STAFF WRITER

Lawmakers say California High Speed Rail Authority work is not just sloppy, but misleading.

Sloppiness was evident: a business plan that never mentioned an Oakland track, a $20 million environmental plan describing a future BART station six months after it opened.

The route into the Bay Area is one of the biggest controversies in the plan for the 700-mile system. The Rail Authority dropped an Altamont Pass route in favor of two South Bay alternatives.

On Feb. 17, Rail Authority Executive Director Mehdi Morshed told the state Senate Transportation Committee that years ago French, German and Japanese rail experts had blessed the plan to run tracks through San Jose rather than over the Altamont Pass.

Morshed couldn't document the claim.

The Train Riders Association of California filed a public records request for all communications with the French, German and Japanese consultants. Morshed provided what he described as a full, unedited set of documents.

"None of the documents we were provided contained any information to support Mr. Morshed's statement," TRAC's Oakland lawyer Stuart Flashman wrote lawmakers.

In a rebuttal letter, Morshed reasserted the documents that led to the Altamont decision "were peer reviewed by German, French and Japanese experts," adding the reviews marked "general agreement."

But a month after Morshed's testimony, Rail Authority Deputy Director Dan Leavitt wrote a Japanese rail expert, asking for "a brief analysis" of the environmental study's conclusion that an Altamont Pass route would be "impractical."

On March 16, Leavitt wrote "the task should take no more than $10,000."

Sunday Feature

Health News
General Health
Women's Health
Men's Heatlh
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Op-Ed
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Bay Area Living
Games
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Columnists
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On April 23, the Japanese expert duly complied with a three-page report, finding "it is reasonable to eliminate the (Altamont) option." On May 10, came the bill. "Cost for the review task: $10,000," the Japanese expert wrote.

Morshed said the letters stemmed from a U.S. Environmental Protection Agency request. A Feb. 27 EPA letter copied to Morshed noted concern that the Altamont route "appears to have been prematurely eliminated." Morshed said his Senate appearance was all a misunderstanding.

"The question was 'Why didn't you study it?' and I said we did," Morshed said. He said he only intended to imply that foreign consultants reviewed the whole plan and "did not find fault with our assumptions," including the Altamont.

"How they construe that to be misleading, I don't know," he said.

But lawmakers on the committee had no doubts. "It sounds like Mehdi said he had a study that predated their decision and it informed their decision. Now it looks like they are making it up as they go along," said Sen. Tom McClintock, R-Thousand Oaks, who sat on the committee hearing.

"I am not surprised that phantom studies are being waved before the Legislature," McClintock added. "I think this entire project has been a fraud since the day it was proposed."

"I don't know how you could interpret it any other way," said Brian Perkins, transportation adviser to Sen. Jackie Speier, D-Hillsborough, who also sat on the committee.

More troubling to Perkins, who called Morshed's actions "not intellectually honest," was a document missing in his public records disclosure. Correspondence between Leavitt and the Japanese expert refers to an e-mail dated Feb. 17 -- the same day Morshed testified.

"It's like the missing 171/2 minutes," Perkins said, referring to the erased gap in the Oval Office tapes that helped force Richard Nixon from the presidency. "They apparently learned from Mr. Nixon that you burn the evidence."

French consultants, working under a High Speed Rail Authority contract, also had offered an opinion to the authority. They noted an Altamont route "would not be practical," and they peer-reviewed the agency's work in 2000 and found it "sound and reliable."

The Feb. 11 letter was written by engineers at SNCF, parent company to Systra Consulting. Systra is one of three firms picked for the "Project Implementation Team," which stands to make $10 million a year if California's rail bond passes.

Flashman said Morshed's team "got back what they wanted" from a firm with an incentive to deliver.

Veteran San Diego lawmaker James Mills, who quit the California High Speed Rail Authority board, is not surprised.

"One of the reasons I left is I couldn't get the truth out of Mehdi Morshed. Mehdi is one of those people who has a hidden agenda on everything," Mills said, "He would only tell the truth when it was convenient."

Mills described the entire project as "based on a fallacy" of wildly exaggerated ridership projections. It stems, he said, "from hiring a consulting firm (and) letting them know what you want them to say."

Morshed said Mills is "full of (it)," describing him as someone who used his position on the board to help California's intercity Amtrak service and undermine the bullet train.

But some Central Valley politicians involved in the rail issue side with Mills.

"Their story changes depending on their audience," Kings County Supervisor Alene Taylor said. "They have not been honest with the public. It's how they do business."

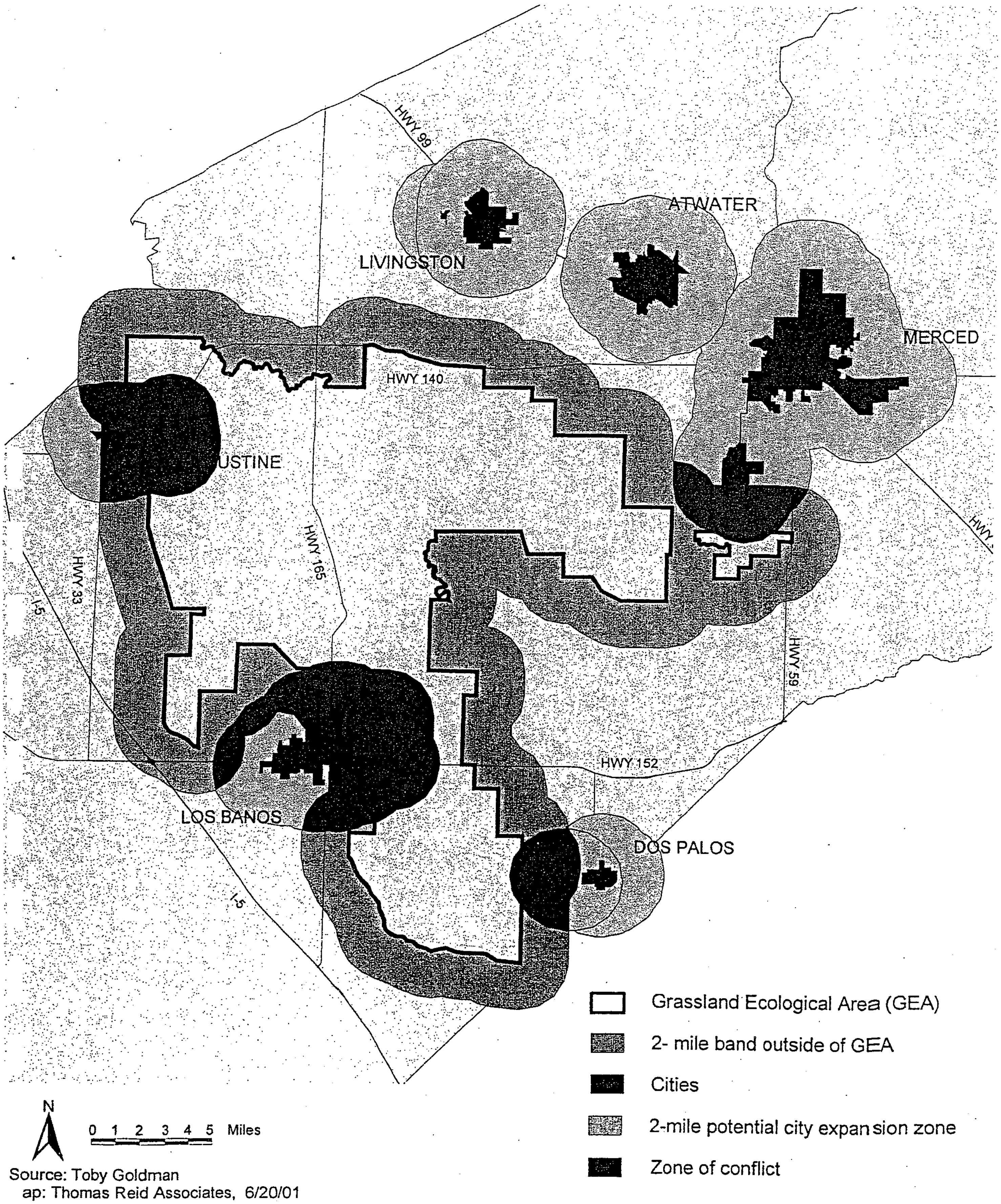
Contact Sean Holstege at sholstege@angnewspapers.com .

RETURN TO TOP

EXHIBIT 14

Grassland GEA Buffer Zones and Zones of Conflict Map

Figure 8
Cities and the Grassland Ecological Area
Zones of Conflict 2040



Source: Toby Goldman
ap: Thomas Reid Associates, 6/20/01

EXHIBIT 15

Dean Kwasi Letter (November 3, 1999)

Grassland Water District

22759 S. Mercey Springs Road
Los Banos, CA 93635
Telephone (209) 826-5188
Fax (209) 826-4984

November 3, 1999

Ms. Lynn Azevedo, Planning Director
City of Los Banos
520 J Street
Los Banos, CA 93635

RE: Draft Environmental Impact Report for the Meadowlands II Development and Annexation/Pre-Zoning, East Los Banos Area Plan

Dear Ms. Azevedo:

Thank you for the opportunity to review and comment on the Draft Environmental Impact Report (Draft EIR) for the Meadowlands II Development and Annexation/Pre-Zoning, East Los Banos Area Plan (Project). In general, the Grassland Water District (GWD) supports the Project and we commend the City of Los Banos and its effort to address and protect the sensitive environmental resources east of the Project site. The following comments are intended to assist the City in addressing some of the potential environmental impacts and deficiencies associated with the Draft EIR.

1 Contrary to assertions made in the Draft EIR, the giant garter snake (*Thamnophis gigas*), a state and federally listed threatened species, is not only historically known to the occur in the Grasslands but has been documented within the last two years in waterways both north and south of the City of Los Banos. As a result of a cooperative research effort between the Western Ecological Research Center, CA Department of Fish and Game, U.S. Fish and Wildlife Service, and Grassland Water District, eleven giant garter snakes were documented in 1998 and sixteen giant garter snakes were documented in 1999 (Wylie 1998, CA Dept. of Fish and Game, *in draft*, 1999). The majority of these snakes were captured, weighed, measured, and marked with passively induced transponder (PIT) tags for future identification. These snakes were caught in both natural channels and water conveyance canals.

It is well documented that the giant garter snake inhabits waterways, including irrigation and drainage canals, sloughs, and low gradient streams (U.S. Fish and Wildlife Service 1999). The San Luis Canal, a major conveyance canal for wetland water supplies to private wetlands, state wildlife areas, and federal wildlife refuges, borders the Project on the east. This canal contains the necessary habitat components for the giant garter snake including; adequate water during the snake's active season, populations of food organisms, emergent, herbaceous wetland vegetation for escape cover and foraging, and grassy banks and openings in waterside vegetation for basking. In addition, the San Luis

Canal has the potential to function as a movement corridor for the giant garter snake, as noted by the Draft EIR, "This species [giant garter snake] may occasionally move onto the Project site by land or via the San Luis Canal (East Los Banos Area Plan Draft EIR, Page 7-3).

2 Considering the San Luis Canal provides potential habitat for the giant garter snake, the standardized survey protocol developed by the California Department of Fish and Game (see attached) should be used to conduct pre-project surveys of the site. The "reconnaissance level survey" conducted for the Draft EIR, while useful for assessing many of the biological resources of the Project site, falls short of the more rigorous protocol used to survey for giant garter snakes. This protocol includes, among other things, surveying for giant garter snakes from April 15-June 1. The reconnaissance level survey was conducted well outside of this time period (October 9, 1998). As a result, the Draft EIR only provides for a 50-foot buffer along the San Luis Canal which is insufficient to adequately protect the giant garter snake from incidental take. Although the giant garter snake usually remains in close proximity to wetland habitats, giant garter snakes can be found as far away as 250 meters (820 feet) from the edge of marsh habitat (G. Hansen 1988, Wylie et al. 1997). We therefore recommend that the buffer be increased to a distance that ensures the giant garter snake is not adversely impacted by the Project. The U.S. Fish and Wildlife Service recommends a minimum buffer of 200 feet from the banks of giant garter snake aquatic habitat. By increasing the size of the buffer, potential impacts to the San Luis Canal and the giant garter snake can be lessened. The open space buffer could be constructed of native trees, shrubs, and grasses and incorporated into the Project design as an urban, non-vehicular trail system.

Thank you again for the opportunity to provide comments. The GWD is appreciative of the professional and cooperative relationship we maintain with the City and we look forward to providing any additional assistance necessary to ensure that the project proceeds in an environmentally sensitive manner. If you have any questions regarding these comments, feel free to contact me at (209) 826-5188.

Sincerely,

Dean Kwasny

Dean Kwasny
Biologist, Grassland Water District

cc: Richard Menezes
Dave Widell
Dan Cardozo

EXHIBIT 16

Caltrans, Map of Los Banos Bypass Alternatives

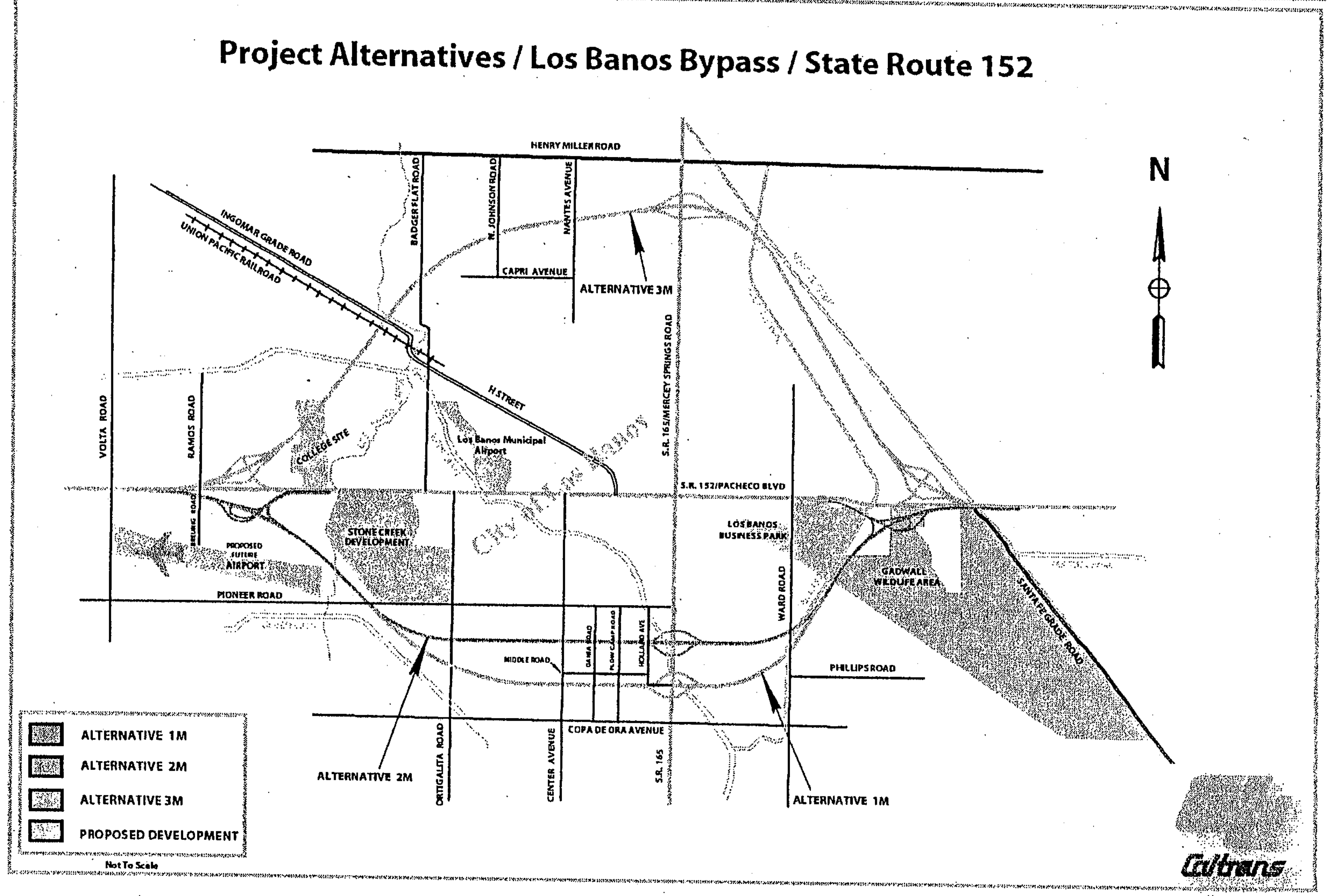


Figure 2-1 Build Alternatives 1M, 2M, and 3M

EXHIBIT 17

Terry Watt Comments and Attachments A-E

Terrell Watt, AICP
Terrell Watt Planning Consultants
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office: 415-563-0543

GROWTH INDUCING IMPACTS OF THE HIGH SPEED TRAIN PROJECT ON THE GRASSLAND ECOLOGICAL AREA

The DEIR/S fails to analyze the growth inducing impacts of the HST project on the Grassland Ecological Area in Merced County.[1] The Grassland Ecological Area is an irreplaceable, internationally significant ecological resource located just north and east of Los Banos. The proposed Pacheco Pass Alignment would bisect this area causing fragmentation and other direct impacts. More ominously, the growth-inducing impacts of locating a train station, the Los Banos Station, in Santa Nella would most likely result in urban encroachment and development pressures that could doom this area. The protection of this area has been the result of private and public partnerships. Much of the area is privately owned managed wetlands used for duck hunting clubs. The DEIR/S makes no mention of this area and fails to address the significant growth inducing impacts of HST alternative on this area. L029-105

CEQA requires that an EIR contain an analysis of a project's growth inducing impacts. Growth-inducing impacts are those that encourage or facilitate other activities or projects that could significantly affect the environment. The "detailed statement" setting forth the growth inducing aspects of a project must "[d]iscuss the ways in which the proposed project could foster economic growth, or the construction of additional housing, either directly or indirectly, in the surrounding environment." CEQA Guidelines Section 15126.2(d). It must also discuss how a project may "encourage or facilitate other activities that could significantly affect the environment, either individually or cumulatively" or remove obstacles to population growth. Population growth in turn may impose new burdens on existing or planned community services. Similarly, NEPA requires that agencies consider the indirect effects of a proposed action, such as growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate. 40 CFR 1508(b). L029-106

The general analysis of growth inducement that is included in the DEIR/S fails to accurately analyze and document the likely growth that could be induced and erroneously concludes that growth induced by HST will be beneficial after mitigation strategies are imposed. Lead agencies L029-107

[1] Ed Thompson, Esquire, President of American Farmland Trust California, contributed to this section. In preparing her comments, Terrell Watt reviewed the applicable general plans and zoning for the proposed Los Banos station and Pacheco alignment in the Grasslands area.

must not assume growth induced in an area is beneficial or of little consequence until it has completed open minded analysis. CEQA Guidelines section 15126.2, subd.(d). Here the DEIR/S conclusions concerning growth inducement are not supported by evidence. The exercise of analyzing growth inducement is technically feasible and must be included in a revised DEIR/S. L029-107 cont'd

Major flaws in the DEIR/S approach to growth inducement include but are not limited to the following:

First, the DEIR/S fails to provide any analysis of the growth inducing potential of the proposed alternatives and in particular of the HST alignment and rail station in the Merced Grasslands area. L029-108 In fact, this important ecological area is not mentioned in the DEIR/S discussions of land use, loss of agricultural land or economic growth and related impacts. L029-109 The proposed Los Banos station is actually located in the small unincorporated community of Santa Nella in the County of Merced, near the small city of Los Banos. The station location is currently general planned for and zoned A-1, General Agricultural in the Merced County General Plan and is adjacent to the Grassland Ecological Area. The Merced County General Plan describes the uses in agricultural areas as follows: L029-110

> The Agricultural Residential land use designation is generally applied to areas considered appropriate for the construction of single-family dwelling units on large lots in a semi-rural environment, with less than a full range of public services. General Plan Land Use Element page I-19.

The General Plan land use map shows a range of large-lot rural parcel sizes in the A-1 areas. While the DEIR/S fails to analyze growth inducing impacts on this specific area, it does conclude that HST would make it possible for people living almost anywhere in the Central Valley to commute to employment centers in Sacramento, the Bay Area and Los Angeles. "Transportation investments can lead to reduced travel time or cost [and] improved accessibility to regions." DEIR/S page 5-1. With respect to the general growth inducing impacts on Merced County, the DEIR/S is clear that the most dramatic increases in employment and population willoccur in that County:

- ...while under the HST Alternative, Merced, San Francisco, and Sacramento Counties are projected to exhibit the highest growth rate. DEIR/S page 5-14. L029-111
- Significant increases in both employment and population would occur with HST in Merced County over 2002 and No Project conditions. See Table 5.3-5 and Figures 5.3-2 to 5.3-4.
- ...the HST Alternative could be a strong influence in attracting higher-wage jobs to the Central Valley. DEIR/S page 5-18 and Tables 5.3-5 to 5.3-7.
- The largest increase in population and employment (4%) would occur in the Northern Central Valley region under the HST Alternative. DEIR/S page 5-23. For example, Merced County would exhibit the largest relative increase in both

population and employment with implementation of the HST Alternative. DEIR/S page 5-25. L029-111 cont'd

- Increased employment opportunities should lead to personal income growth in all regions of the state; this growth might be most pronounced in counties of the Northern Central Valley under the HST Alternative, since that region is projected to experience the largest employment gain. DEIR/S at 5-26.

Elsewhere, the DEIR/S concludes that HST will increase population by only 162,000 more than the 6.5 million new residents expected to be in the Central Valley by 2035, accounting for only 3% of the projected increase (above). The "blackbox" growth model by Cambridge Systematics, Inc., (CSI), which underlies the DEIR/S analysis, bases its conclusions concerning growth inducement on the number of jobs within a 90-mile radius. Notwithstanding the overwhelming evidence that this approach applied to remote areas like the Grasslands would result in tremendous growth pressure, the DEIR/S concludes that HST will make little difference in the future population of the Central Valley. This conclusion is simply wrong.

As recent growth patterns have indicated elsewhere in California, accessibility to major employment centers has triggered tremendous new growth.[2] The introduction of HST to the Grasslands area will make it possible for Bay Area residents to easily commute to and from them affordable suburban and rural housing in and around the Grasslands area and create significant pressure for growth of housing and new services in the area. That pressure will extend to the privately held lands in and around the Grasslands that are not permanently protected. Additional growth in the area also poses significant indirect threats as a result of increased population and pressure on farmlands and open space. The Merced County General Plan and Los Banos General Plan's lend themselves to a pattern of suburban and rural sprawl due to the predominance of low density general plan and zoning. The relative affordability of homes and property in the area will be a tremendous draw for Bay Area workers to move to the area.[3] A revised DEIR/S must disclose and analyze the likely growth inducing impact of HST on the area including how introduction of the station is likely to accelerate growth and increase demand for subdivisions and development.

Second, the DEIR/S conclusions that HST will lead to more efficient use of the land and higher densities are simply not supported by the general plans or by evidence in the DEIR/S. Incredibly, the DEIR/S concludes that the HST Alternative will result in significant land use efficiencies over both the No Project and Modal Alternatives: L029-112

[2] Examples include the Auburn corridor as major new employers moved to the Sacramento region and north; the Truckee area which is approximately 1 hour from the major new job growth in the Auburn Corridor and Reno. Historical growth patterns in California clearly demonstrate that the close proximity of a major job center inevitably leads to growth inducement for housing within commute range. HST will render the Grasslands area within close commute range to major job centers in the Bay Area.

[3] As of the 2nd quarter of 2004, a median priced home in Merced County cost $228,000 and in Los Banos cost $265,500. By comparison, during the same quarter a median priced home in San Jose cost 507,750, nearly twice the cost of median priced home in the area near the proposed Los Banos station. In Gilroy during the same period, a median priced home cost $550,000. See Attachment A hereto, California Real Estate Statistics for Merced and Santa Clara counties.

- "The efficiency for the HST Alternative is achieved in conjunction with the highest population and employment growth rates of all alternatives and would be 6.3% more efficient than the Modal Alternative." DEIR/S page 5-22. L029-112 cont'd

- The HST Alternative provides an increments development density that is 4% more efficient than the No Project Alternative, while the Modal Alternative is 2.3% less efficient than the No Project Alternative. DEIR/S page 5-22 and Table 5.3-7.

This result is not likely in areas planned and zoned for very low densities. General Plans and zoning for both the County and Los Banos in the Grassland area call for very low density development.[4] The typical development density in the limited High Density development areas in Los Banos is only 15 units per acre. Most of the residentially designated vacant land in the City is in the Low Density and Very Low Density designations ranging from 1 to 7 units per acre. Hundreds of acres of land are in these low density categories would experience high development pressures if HST is introduced to the area. Los Banos General Plan pages LU-3 – LU5. Merced County's land use designations in unincorporated communities such as Santa Nella (population approximately 500 persons), also provide for low densities consistent with the agricultural surroundings and lack of a full range of services.

The DEIR/S fails altogether to analyze the HST's role in inducing low density suburban and rural residential development. This is among the document's major flaws. The DEIR/S ignores the "ranchette phenomenon," which is the worst type of sprawl.[5] Census figures make it possible to separate rural and urban populations. The DEIR/S simply fails to consider the tremendous demand for this type of development and therefore fails to identify and analyze the additional significant impacts related to that growth including increased traffic, increased pollution, L029-113 increased demand for services and infrastructure, accelerated and increased loss of open space, agricultural and habitat land. The market forces set into motion by HST are likely to create pressure for dramatic changes to the County general plan and accelerate development in the area. In fact, new transportation facilities are classic for inducing and redirecting significant growth.[6] In this case, the construction of the HST alignment and station in this relatively undeveloped and rural area will likely induce growth permitted by the general plan, prompt general plan and zoning amendments for additional growth and accelerate both urban and rural development.

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[4] While the DEIR/S states that the Cambridge Systematics study considered county general plans and policies, there is no evidence of this in the report. DEIR/S page 5-8. Moreover, the section identifies for subsequent analysis "Land use studies for specific alignment and station areas potentially impacted, including evaluation of potential land use conversion, potential growth, and potential community benefits." DEIR/S page 3.2-27. These are all analyses that must be included in a revised DEIR/S prior to any action on the project.

[5] The analysis completed by the American Farmland Trust (see comment letter submitted by AFT), suggests that between 300,000 and 700,00 additional acres of land could be converted to rural ranchettes based on population projections, current ranchette development trends and assuming an average of 5 acres per dwelling and 2.8 persons per household. This trend will accelerate the subdivision of open space lands for ranchette development where HST removes the barrier of accessibility to jobs.

[6] There is significant academic research on the topic of transportation and growth. A literature search provided a number of key papers, which support the strong link between the introduction or expansion of transportation systems (including rail and roads) and redirected growth. A major study by Professor Robert Cervero of the UC Transportation Center concluded that: "...real estate investment has gravitated to improved freeway corridors..." (page ii) and that "The preponderance of empirical evidence to date suggests that induced effects [of new and expanded roadways] are substantial." (page 1). See Attachment B.

Without analysis of facts the DEIR/S concludes that HST will minimize a variety of impacts normally associated with growth due to its inherent incentives for directing urban growth: L029-113 cont'd

> "In short, the HST Alternative provides a strong incentive for directing urban growth and minimizing a variety of impacts that are frequently associated with growth. This outcome would be seen in results for resource topics such as farmland, hydrology, and wetlands, where the indirect effects of the HST Alternative are less than the Modal Alternative, and in some cases less than the No Project Alternative, even with more population and employment expected with the HST Alternative." DEIR/S page 5-34.

> "Nonetheless, the results indicate that the HST Alternative would be able to accommodate more population and employment growth on less land than the other alternatives." DEIR/S page 5-10.

The DEIR/S continues on to conclude that the growth potential with HST is "potentially beneficial" with mitigation strategies. DEIR/S Table 7.3-1. These conclusions are not supported by adequate and transparent analysis or substantial evidence. Review of the applicable general plans in the Merced Grasslands area suggests that the introduction of HST will not only induce significant new growth but that the growth will occur in suburban and rural sprawl patterns most harmful of habitat areas and farmland. Major studies have also shown that the introduction of transportation facilities redirects growth. In this case, if alignments and stations are located in rural areas, growth and development in California could actually be redirected away from existing urban areas and into more remote rural areas where high value agricultural and habitat lands occur. See Attachment B. This would be far from a "smart growth" or beneficial effect of HST. A revised DEIR/S must indicate the likely increase in subdivisions of rural land and map those privately owned lands that will be subject to growth and development pressures.

Third, the DEIR/S fails to disclose the likely increase in demand in areas served by HST for second homes. The spectacular open space setting in and around the Grasslands area is highly attractive for a second home market. The DEIR/S is silent on this potential growth inducing impact. The market for second homes has increased along with disposable income of the large baby boom segment of the population.[7] A revised DEIR/S must include analysis of this potentially significant impact on rural areas proposed to be served by HST. L029-114

Fourth, the new Los Banos station is likely to require major new infrastructure and services. The DEIR/S fails to reveal the extent of these facilities nor does it analyze the growth inducing impact these new facilities will have in the immediate area of the station. A revised analysis must include information about the types of services and infrastructure needed for the station and how the extension of those facilities will remove an existing barrier to growth in the area. Specifically, the DEIR/S should describe the current general plan and zoning of the station site and surrounding areas; the existing status of services and infrastructure; services and infrastructure that will be provided to serve the station; and the likely growth inducing effect of the station and those facilities on adjacent lands. L029-115

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[7] See Attachment C, Baby Boomer Investors Fueling Second Home Market Sales.

Fifth, the DEIR/S discussion of economic and growth inducement suggests that the introduction of HST to the Central Valley will change the types of jobs in the region and lead to personal income growth: L029-116

- Increased employment opportunities should lead to personal income growth in all regions of the state; this growth might be most pronounced in counties of the Northern Central Valley under the HST Alternative, since that region is projected to experience the largest employment gain. DEIR/S at 5-26.

The DEIR/S fails to analyze the likely results of this dramatic change, including, but not limited to increased demand for larger, high end homes, increased demand for services and overall increased in growth and development to serve the very different demands of higher income individuals and families.

Finally, the mitigation strategies for growth inducement are not sufficient. While increased concentration of development around HST stations in downtown locations has the potential to avoid or minimize some impacts, the opposite is likely to be the case where stations are located in rural areas. The Cambridge Systematic study suggests that "regulatory style efforts to encourage increased density and a mix of land uses near rail stations have been effective." However, they also acknowledge that an exception to this would be the stations located outside the downtown areas of cities in the Central Valley. Moreover, specific mitigation measures, such as urban growth boundaries, transit oriented development district planning and zoning, housing density and affordability requirements and the like directed at avoiding sprawl must be in place prior to HST development. Studies that have evaluated the relationship of new transit stations and development have largely concluded that: "...land use benefits from investments in rail transit are not automatic. Rail transit can contribute to positive change, but rarely creates change by itself. The hardware needs software – supportive land use policies such as density L029-117
bonuses and ancillary infrastructure improvements – if it is to reap significant dividends." Attachment D, page 15. Similarly, Professor Cervero's studies have concluded that better land use planning and management is essential to securing "smart growth" outcomes. See Attachment B.

Mitigation measures that must be included in a revised DEIR/S include, but are not limited to the following:

- Requirements" for agreements with cities/counties the route traverses for "smart growth" policies (e.g. in downtowns around stations specific programming for higher densities, etc.; in rural areas specific policies for farmland protection, etc.). Such measures could include rewarding cities that adopt higher, mixed used densities with funding and other incentives. The Metropolitan Transportation Commission is currently studying the relationship between land use policies and transit ridership. Policy options under study include requiring supportive land use policies in return for transit funds. See Attachment E.
- Up-front purchase of conservation and agricultural easements to either side of the tracks and stations where located in undeveloped areas outside of cities and, within and around the boundaries of the GEA.

- Establishment of urban growth boundaries in communities traversed by HST and stations are located;
- Limits on new subdivisions outside of urban growth boundaries and the like.

L029-117 cont'd

Even with these measures identified in a revised DEIR/S, additional evidence must be provided that they would actually have the desired affect in rural areas.

If they are wrong, CSI concedes that the model would produce a very different result, presumably a much greater impact on the Central Valley.

> "While the exact role of particular factors [shaping land development patterns] varies by region, several influences are consistently important, including proximity to freeways, access to jobs, site slope and site incorporation status. To the extent that these factors are less important in the future, or are important in different ways – or, as is even more likely, that other factors become important – the model results will vary widely than [sic] what is presented here." CSI, at H-5

Based on empirical evidence, highly regarded academic studies of the relationship of transportation and growth and proximity of job centers to growth, the introduction of an HST alignment and station will have a substantial and adverse growth inducing impact on the Los Banos, Merced area. Stated in clear terms, the DEIR/S and CSI have incorrectly concluded that the growth inducing effects of HST will be insignificant and possibly even beneficial. A revised DEIR/S must include a completed revised and transparent analysis of the significant and likely adverse growth inducing impacts of HST where it is located in rural areas of California, including the Los Banos, Merced area. The new analysis must include effective mitigation measures capable of reducing or eliminating these significant effects, such as those listed above. The benefits of HST may be realized, but only if the project is redirected to serve existing urban corridors and strong land use policies are required in advance of its construction to ensure that HST does not lead to sprawling suburban and rural development and loss of high value California landscapes such as the irreplaceable Grassland Ecological Area in Merced County. L029-118

ATTACHMENT A

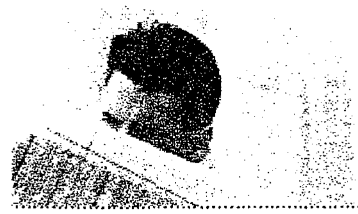
CAR statistics

	2nd Qtr 2004	2nd Qtr 2003	
Merced County	$228,000.00	$188,000.00	21.3%
Atwater	$217,000.00	$177,000.00	22.6%
Los Banos	$265,500.00	$240,000.00	10.6%
Merced	$215,000.00	$185,000.00	16.2%

Santa Clara County	$540,000.00	$469,000.00	15.1%
Campbell	$566,000.00	$486,000.00	16.5%
Cupertino	$755,000.00	$674,000.00	12.0%
Gilroy	$550,000.00	$470,000.00	17.0%
Los Altos	$1,350,000.00	$1,115,000.00	21.1%
Los Gatos	$920,000.00	$735,000.00	25.2%
Milpitas	$503,000.00	$419,000.00	20.0%
Morgan Hill	$624,000.00	$520,000.00	20.0%
Mountain View	$575,000.00	$500,000.00	15.0%
Palo Alto	$857,500.00	$699,250.00	22.6%
San Jose	$507,750.00	$440,000.00	15.4%
Santa Clara	$535,000.00	$487,500.00	9.7%
Saratoga	$1,175,000.00	$1,108,000.00	6.0%
Sunnyvale	$575,000.00	$500,000.00	15.0%

Median home prices contained in this chart were generated from DataQuick Information Systems. The price statistics are derived from all types of home sales – new and existing, condos and single-family. Movements in sales prices should not be interpreted as changes in the cost of a standard home. Median prices can be influenced by changes in cost, as well as changes in the characteristics and size of homes sold. Due to the low sales volume in some cities or areas, median price changes may exhibit unusual fluctuation. N.A. = Not available.

ATTACHMENT B



May 8, 2003

New Study Finds Roads Just Redistribute Growth

Changes in Transit-Oriented Development Could Balance Disparities

WASHINGTON, DC — Highway critics have focused on the way new roads increase congestion when they should be looking at how road improvements redistribute regional growth, contends Robert Cervero, a University of California at Berkeley planning professor and author of a groundbreaking study published in the Spring 2003 issue of the *Journal of the American Planning Association* (JAPA).

Click here to read the complete article

"Roads induce growth at a corridor scale; however they don't do so at a regional scale," Cervero found. "Induced growth along [highway] corridors is really redistributed regional growth."

The article is titled "Road Expansion, Urban Growth, and Induced Travel: A Path Analysis," and was supported by a grant from the University of California Transportation Center.

Cervero's findings could have significant impact on billions of dollars of road projects as traffic forecasters try to unscramble the tangled interaction between congestion and new development. Many regional transportation plans have been mired in political squabbles over whether new roads increase sprawl and the extra vehicle trips associated with it. Highway critics have long claimed that improved roads fuel "induced demand" — additional travel or diverted trips from parallel routes. Cervero's new research indicates that the claim might be exaggerated.

"The contention that capacity additions are quickly absorbed by increases in traffic and that "you can't build yourself out of traffic congestion" might not hold in all settings," he found.

How road expansions induce development along highways — a phenomenon Cervero calls "induced growth" — may be more important than whether highway expansions decrease congestion.

"Congestion relief ... does not necessarily make for a sustainable and livable metropolis," Cervero observed. "Thus residents of places that are able to build themselves out of traffic congestion might not necessarily like what they get."

"This is an important article on a very complex topic," said Stuart Meck, FAICP, a senior research fellow with the American Planning Association (APA). "State transportation departments often claim that they are only serving existing development, but this study shows that capacity improvements actually make matters worse in some cases, although the time frame is longer than many believe — as long as five to six years."

Cervero found that, over time, road improvements and the resulting swifter travel speeds spur building activities along highway corridors. That growth fuels more traffic which then erodes most of the speed benefits of added capacity.

"The dominant effect of building roads is likely to reshuffle growth within a region, not to add jobs and households," he concluded.

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Cervero's findings point up the need to do a much better job in managing regional development to balance the growth induced through highway expansions, Meck said.

One solution may be better planning of transit-oriented development (TOD). In an article in the May issue of *Planning* magazine, Cervero suggests that TOD in the United States is deterred by the huge parking lots surrounding metropolitan transit hubs.

"Not only do the big lots consume real estate near stations, but they also create unpleasant and sometimes unsafe walking environments," he notes.

Cervero touts "Green Connectors" — networks of pedestrian and bicycle friendly avenues that feed into major transit routes — as replacements for the asphalt jungles that take up valuable space that could be used for TOD. Green connectors have had enormous success in Europe and parts of Latin America. Cervero believes that carefully crafted public policies and planning visions can make them work here.

"If cities as varied as Stockholm and Bogota can successfully implement green connectors to trunk-line transit, so can American cities and suburbs," he claims.

Skeptics contend that experiences from Europe and Latin America cannot be imported successfully to the U.S. with its culture of independence and long love affair with the automobile.

That's hogwash, responds Cervero.

"Americans reveal their distaste for walking in unappealing environs by going great lengths to find a parking spot close to a shopping mall entrance. Yet they think nothing of walking one or two miles once inside," he notes.

"The difference is that malls are generally dreary on the outside but engaging on the inside — a useful lesson for other places."

Whether highway expansions will redistribute regional growth and whether green corridors can jump start the kinds of TOD that can offset those effects will all depend on strategic transportation planning based on sound econometric modeling. Cervero's studies and creative ideas provide a starting point in developing robust models for creating more livable communities.

Click here to subscribe to the *Journal of the American Planning Association* (JAPA) and *Planning*.

Contacts
Chris Cooper, APA Public Affairs, 202-872-0611 x1007

Road Expansion, Urban Growth, and Induced Travel: A Path Analysis

Robert Cervero
Department of City and Regional Planning
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Abstract

Claims that roadway investments spur new travel and thus fail to relieve traffic congestion, known as induced demand, have thwarted road development in both the United States and abroad. Most past studies point to a significant induced demand effect. This research challenges past results by employing a path model to causally sort out the links between freeway investments and traffic increases, using data for 24 California freeway projects across 15 years. Traffic increases are explained in terms of both faster travel speeds and land-use shifts that occur in response to adding freeway lanes. While the path model confirms the presence of induced travel in both the short- and longer-run, estimated elasticities are generally lower than those of earlier studies. This research also reveals significant "induced growth" and "induced investment" effects – real-estate development has gravitated to improved freeway corridors and road investments have been shaped by traffic trends in California. Fighting road projects on the grounds of induced-demand should be carefully considered. Energies might be better directed at curbing mis-pricing in the highway sector and managing land-use changes spawn by road investments.

Road Expansion, Urban Growth, and Induced Travel: A Path Analysis

Few issues in the urban transportation field have sparked as much controversy and threatened proposed road projects as claims of "induced demand". For decades, highway critics have charged that building new roads or expanding existing ones to relieve traffic congestion is a futile exercise. Improved roads simply spur additional travel or divert trips from parallel routes, quickly returning a facility to its original congested condition. Traffic is thought to behave more like a gas than a liquid – it expands to fill available space. Regional transportation plans, such as in the San Francisco Bay Area, have been mired in legal and political squabbles on the very grounds that they failed to account for the possibility that new roads might induce sprawl and the extra trips associated with it. Claims of induced demand have spawned such clichés as "build it and they will come" and "you can't pave our way out of traffic congestion".

The preponderance of empirical evidence to date suggests that induced effects are substantial. A widely cited study by Hansen and Huang (1997), based on 18 years of data from 14 California metropolitan areas, found every 10 percent increase in lane miles was associated with a 9 percent increase in vehicle miles traveled (VMT) four years after road expansion, controlling for other factors. Another study of 70 U.S. metropolitan areas over a 15-year time period concluded that areas investing heavily in road capacity fared no better in easing traffic congestion than areas that did not (Surface Transportation Policy Project, 1998). Based on a meta-analysis of more than 100 road expansion projects in the United Kingdom, Goodwin (1996) found that proportional savings in travel time were matched by proportional increases in traffic on almost a one to one basis, a finding that prompted the U.K. government to jettison its longstanding policy, "predict and provide", of responding to traffic-growth forecasts by building more motorways.

With the cumulative weight of evidence on induced demand threatening road projects in many parts of the United States, it bears noting that past research has recently come under fire on methodological grounds. Many studies can be faulted for failing to introduce a normative behavioral framework for tracing impacts, one that accounts for intermediate steps between road improvements and traffic growth and that allows for two-way causality (DeCorla-Souza and Cohen, 1999; Cohen, 2001; Pickrell, 2001; Cervero, 2001).

Using data for a panel of California freeways, this paper aims to fill past methodological gaps by postulating and empirically testing a path model of induced travel. A short-run model, which focuses on relationships within a one-year time frame, holds that changes in road supply affect travel speeds, which nearly instantaneously affect traffic levels. In contrast to most recent analyses of induced demand that measure VMT growth as a direct function of lane-mile additions, this analysis introduces an important intermediate step – namely, that road improvements confer benefits, in the form of higher travel speeds, and that it is changes in operating conditions that influence demand, not the physical attributes (e.g., lane miles) of a project. A longer-run model traces how road investments induce major building activities over a multi-year time horizon, and how resulting land-use shifts in turn lead to increased travel. A feedback loop is also modeled, capturing how traffic growth influences road investment decisions.

Econometric models are called upon to sort out the relative influences of land-use shifts in stimulating traffic vis-à-vis travel behavioral adjustments that are normally associated with induced demand. To the degree that induced travel is found to be a consequence of long-term structural adjustments, land-use management and planning gains all the importance as a tool for managing traffic levels.

1. The Anatomy of Induced Demand

Road improvements are thought to have distinct near- and longer-term impacts. In the short run, increased capacity prompts *behavioral* shifts – some formerly suppressed trips are now made (i.e., latent demand), and some motorists switch modes, routes, and times of travel to exploit available capacity, what Downs (1962, 1992) calls "triple convergence". For example, those who previously patronized transit to work might decide to drive once they see traffic flowing more smoothly. Some who previously commuted on the shoulders of the peak might start filling freeway slots that are vacant in the heart of the peak. Over the longer term, *structural* changes can be expected. Notably, people and firms locate to exploit the accessibility benefits created when freeways are upgraded. The consequences dot America's landscape: fast-food restaurants, gas stations, and other auto-oriented uses cluster around interchanges, warehouses align themselves along frontage roads, and new residential subdivisions spring up along connecting arterials (Hartgen and Kim, 1998; Hartgen and Curley, 1999).

Some of the traffic gains spawn by a new or improved road are *generative* in nature and some are *redistributive*. The former represents new travel that did not previously exist in any form. Included here are formerly suppressed trips, longer trips as motorists opt to travel farther because of freer flowing traffic, and modal shifts. Route and schedule changes, on the other hand, are redistributive in the sense that they do not increase total miles traveled (assuming trips do not become more circuitous).

Short of placing an electronic tag on each traveler affected by a new road and monitoring his or her travel, disentangling the many contributors to increased travel – at least to a high degree of precision – can be a futile exercise (Bonsall, 1996). For this reason, many past studies have examined the magnitude of traffic increases following a road improvement for *all* sources combined. Some studies have employed county- or metropolitan-level data to trace the influences of aggregate increases in lane-miles on aggregate increases in vehicle miles traveled (VMT) (for example: Hansen and Huang, 1997; Noland and Cowart, 2000; Fulton, *et al.*, 2000). This helps to net out redistributive trips since route diversions occur largely within the unit of analysis, although the downside of such aggregate analyses is they are more easily prone to ecological fallacies when drawing statistical inferences.

Many past empirical studies have applied simplified model structures to gauge "induced demand" effects. Often, traffic increases are treated as a direct consequence of lane-mile additions. It is not the lane miles of roads that prompt people to travel more, however. Rather it is the benefits that the lane miles confer. Only if travel speeds increase and travel times fall will motorists gravitate to an improved corridor. Adding a 12-foot lane matters along a highly congested urban corridor; adding one to a lightly trafficked exurban stretch really does not. A firmer econometric framework is needed to help unravel the imbedded, often intricate relationship between road investments and traffic conditions.

2. Toward a Normative Theory: A Path Model

Figure 1 presents a path model for tracing the effects of road improvements on travel demand as well as urban development. The diagram's solid lines represent near-instantaneous impacts, occurring within a year's time. The dashed lines represent longer-term adjustments, signifying the need for a lagged model structure. In the transportation and land-use arena, delayed responses to "stimuli" like road improvements reflect

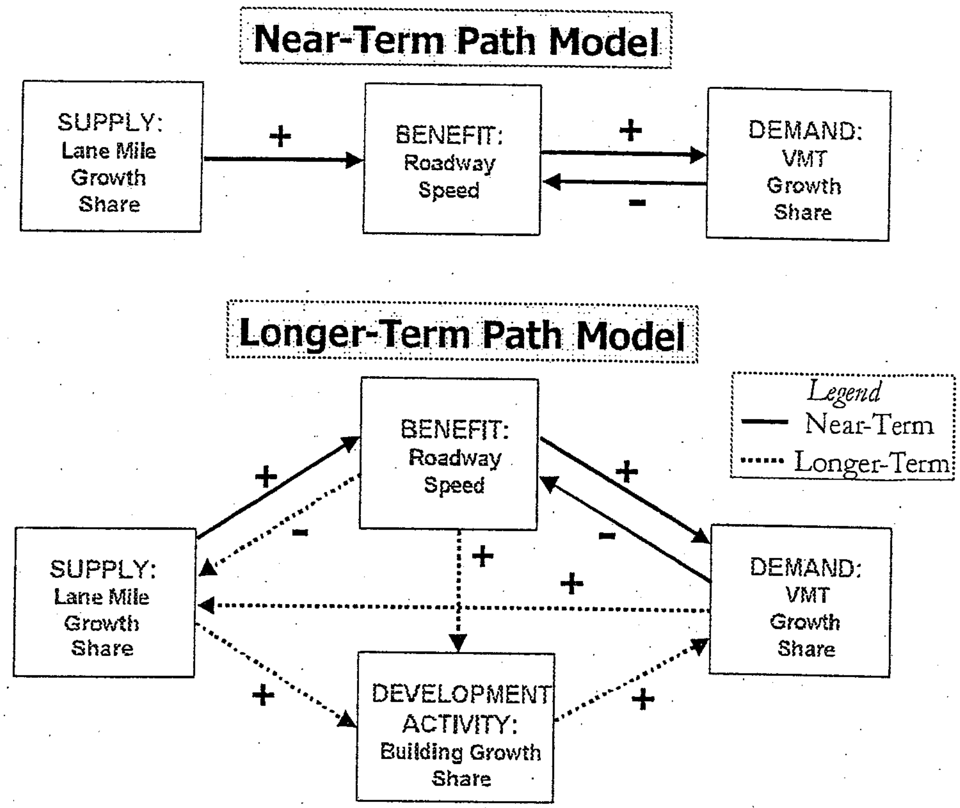


Figure 1. Hypothesized Path Model

institutional lags – such as the need for local planning agencies to rezone land to accommodate new growth or time spent by real-estate developers securing building permits and bank loans.

The path diagram also informs the model estimation process. In the case of uni-directional relationships (in both the near-term and longer-term models), ordinary least squares (OLS) provides efficient, unbiased estimates (as long as OLS assumptions are met). Estimation of two-way, co-dependent relationships hinges on the time structure. Where two variables, like travel speed and demand, nearly instantaneously influence each other, OLS will produce biased parameter estimates. This is because speed and demand are endogenously related. Accordingly, instrumental variables are needed to reduce simultaneous-equation biases. Where two variables are jointly related, and variable X influences variable Y nearly instantaneously but Y's effect on X is delayed over several years, OLS will generally provide suitable parameter estimates. Because the co-dependence is not contemporaneous, the value of one variable, by definition, will be pre-determined in relation to that of the other. For example, while a road improvement can be expected to have a near-immediate effect on travel speed, the effects of eroding speeds over time (once travel demand has risen) on the decision to further expand a facility unfold over a number of years. Econometrically, the values of travel speed in time period (t-n) are already known in relation to the values of road capacity in the current time period (t). Thus, wherever a solid path-line operates in both directions between two variables, multi-stage (e.g., two-stage or three-stage) estimation is called for. Wherever one path-line is solid and the other is dashed in a two-way relationship, instrumentation is unnecessary.

Effects of Road Improvements on Travel Speeds

This link is missing from most past studies of induced demand. Economic theory holds that road improvements spur behavioral changes in travel by reducing "generalized costs", expressed mainly in terms of travel times. Over a fixed distance, there is a one-to-one correspondence between changes in average travel times and average speeds. In this study, average recorded operating speeds over a one-year period for each study corridor is used to gauge reductions in generalized costs.

Effects of Road Improvements and Travel Speeds on Urban Development

In congested urban settings with reasonably vibrant economies, real estate developers scramble to acquire and develop properties with good regional roadway access. Parcels well-served by roads can yield handsome profits (Voith, 1993; Boarnet and Chalermpong, 2001). Two forces are set into motion that influence the decision to develop a parcel, and for modeling purposes help to define a time-lag structure. One is the announcement and construction of road improvements. Developers are well aware of roadway projects slated for construction under regional Transportation Improvement Programs and position themselves to take advantage of planned public improvements. Due to institutional delays, however, it can take several years before necessary permits are secured. A five-plus year time lag between project announcement and new development is not uncommon. The time lapse between when capacity is actually added and induced development occurs is likely shorter, often on the order of two to three years.

Besides the opening of new lanes, actual operating conditions are also thought to influence the scale of land-use changes, at least at the margin. Higher speeds provide confirmation, demonstrating first-hand that there are advantages to owning or leasing properties along a particular stretch of roads. The combination of past-year road investments and recent trends in operating speeds are thought to influence the amount of development added within a buffer zone of a freeway.

Effects of Travel Speeds and Urban Development on Travel Demand

It is this link of the path diagram that encapsulates the idea of induced demand. The model postulates that the combination of current operating speeds on a roadway and previous-year changes in urban development influence current-period demand levels. Both factors are thought to increase VMT -- the former in the near term, the latter over the longer run.

Effects of Travel Demand and Speeds on Road Improvements

Figure 1 also accounts for "induced investment" effects. Notably, changes in a project's share of countywide VMT over time can be expected to influence future shares of countywide road improvements targeted at the corridor, as will trends in travel speeds. Indeed, a criticism leveled at past induced demand studies is they ignored this feedback loop. Roads not only stimulate but also respond to demand. Using 60 years of data, a study by the Urban Transportation Center (1999) found that road improvements in metropolitan Chicago could be better explained by population growth a decade earlier than vice-versa. Over time, it is this combination of "induced demand" and "induced investment" effects that yields some degree of partial equilibrium between road supply and demand.

3. Methodology and Data

For purposes of empirically testing the hypothesized path model, a system of log-linear equations was specified and estimated. In this functional form, coefficient estimates represented elasticities, revealing the proportional change in one variable as a function of a proportional change in another, all else being equal. For the longer-run analysis, the estimated equations took the following form (with all except the fixed effect variables expressed as natural logarithms):

Speed Model:	$B_{it} = f(S_{i,t}\ D_{i,t}\ C_{i,t}\ T_t\ P_i)$
Development Model:	$L_{it} = f(B_{i,t-n}\ S_{it-n}\ C_{i,t}\ T_t\ P_i)$
Demand Model:	$D_{it} = f(B_{i,t}\ L_{i,t-n}\ C_{it}\ T_t\ P_i)$
Supply Model:	$S_{it} = f(D_{i,t-n}\ B_{i,t-n}\ C_{it}\ T_t\ P_i)$

Where:

B = Benefit vector (e.g., mean operating speed)
S = Supply vector (e.g., lane miles)
D = Demand vector (e.g., vehicle miles traveled)
L = Land-Use vector (e.g., building square footage)
C = Control vector (e.g., median personal income in area)
T = Time-series fixed effect (0-1 "dummy variable")
P = Project fixed effect (0-1 "dummy variable")
i = Project cross-sectional observation
t = Time-series observation
n = Length of time lag

With this formulation, benefits and demand are jointly related, thus endogenous variables (i.e., operating speed and VMT) were predicted as functions of pre-determined (exogenous and lagged-endogenous) variables. Given the lagged, pre-determined nature of other endogenous variables, other equations were predicted using ordinary least squares. Also, various time-lag specifications were attempted in the analyses that follow. Before turning to the results, background information on data sources, the sampling frame, and approaches used to measure and impute certain variables are reviewed below.

Data Sources

Records on freeway expansions throughout California were obtained from the California Department of Highways (CalTrans) for years that matched the time span (1980 to 1994) of annual records on building activities obtained from the U.S. Census Bureau. Census records on land-use additions were turned to because, among available secondary sources, they provided the most disaggregate and consistently reported time-series data. Project contracts archived by CalTrans supplied needed information on freeway improvements: the project name and location, number of lanes added, and the length of improved segments.

Sampling Frame

Only freeway expansion projects that occurred in small to medium-size municipalities in suburban settings were chosen for the analysis. This constraint was necessary because of how land-use changes were measured and how building activities were reported. A two-mile "impact zone" around the centerline of each improved freeway project was chosen to gauge development impacts, forming a four-mile wide buffer. However, building data from the census bureau were available only down to the municipal level. To ensure that the impact zone encompassed a significant share of a municipality's land area, only freeway projects that traversed or skirted small-to-medium size cities were considered for the analysis. In all, 24 freeway-expansion projects over the 1980 to 1994 period (representing 360 data points) were chosen on the grounds that four-mile buffers encompassed at least 40 percent of the land area of municipalities that were either traversed or that directly bordered the improved facility.

Variable Measurement

The core variables from Figure 1 that were measured in aggregate units -- notably, lane-mile of roads, building-permit additions, and VMT – were expressed in proportional terms for carrying out the path analysis. Specifically, these variables were defined as shares of countywide totals – e.g., "VMT proportion" represented the share of VMT on all state-owned freeways and highways in a county that occurred on a particular facility for a particular year. In this sense, core variables were expressed as "market shares". If the countywide share of total road-mile additions along a freeway corridor increases, this research hypothesizes that this will be followed by an increase in the share of countywide building activities within a four-mile buffer and that this in turn will be followed by increases in the share of countywide VMT recorded along the facility. Expressing aggregate variables in proportional terms meant that sub-regional trends and conditions were imbedded in the analysis.

The biggest measurement challenge involved estimating building activity within four-mile buffer zones. Using a Geographic Information Systems (GIS) street layer as a guide, paths of the 24 selected freeway projects were digitally traced. Next, four-mile buffers were formed around each project segment and superimposed onto a GIS layer of municipal boundaries. From this, the percentage of land area of each affected municipality that lied within the four-mile buffer was determined. It was assumed that the share of a municipality's building activities within a four-mile buffer matched the share of that municipality's land area within the same buffer. This implicitly assumed that land-use densities were uniform within a municipality. This was felt to be a reasonable assumption given that densities tend to be fairly similar in most small-to-medium size suburban municipalities – the places traversed or bordered by the freeway projects that were studied. To the degree that errors were introduced in imputing building activities within four-mile buffers, there was no reason to suspect such errors were systematically biased.

Census records contained fairly detailed information (e.g., square-footage, number of units) on building activities, drawn from municipal and county building-permit records, across major residential and commercial land-use categories. To empirically test the "induced growth" hypothesis, a composite variable of "building activity" was created for each freeway corridor, gauging the relative degree of countywide development that occurred within a four-mile-wide impact zone. Creating such a variable was necessary since VMT changes were thought to be less sensitive to particular land uses than the overall amount of building activity that took place within a corridor. Because building-permit data on the "scale" of activities reported by the Census Bureau differed among land uses, a composite variable was needed. (For example, residential development is report by number of housing units whereas industrial growth is tracked in terms of building square footage.) The composite represented a weighted average of countywide proportions of each of the six land-use categories: single-family residential; multi-family residential; offices; retail; industrial; and other (representing mainly public and institutional uses). Weights were based on total square footage estimates for each land-use category. Local data on average building sizes were used to estimate total square footage of housing units, offices, and retail establishments.[i]

Induced Travel Versus Induced Demand

As noted previously, not all of the changes in VMT that occur along an improved roadway are truly "induced demand" since some of the traffic growth migrates from other facilities, and will thus be redistributed. The term "induced travel" is often used to represent all changes in trip-making that are unleashed when a road is improved, not only in terms of newly added traffic but also in terms of diverted trips from other routes (Hills, 1996; Lee, *et* *al.*, 1999). This distinction is important, and many previous studies have failed to carefully distinguish "induced demand" from "induced travel". Because this study examines VMT at the facility level, and there is no way to know from reported VMT data how much is diverted, "induced travel" is the focus of the research that follows.

4. Project List, Variables, and Descriptive Statistics

Table 1 lists the 24 freeway projects that formed the panel used to carry out the analyses, and Map 1 shows their locations within nine of California's 56 counties. Nineteen of the freeway segments studied were in four "mature suburban" counties: Contra Costa, Santa Clara, Orange, and Alameda. As limited-access, high-performance facilities, freeways provide favorable contexts for gauging induced travel and land-use impacts, particularly in fairly congested, fast-growing settings such as many of the California corridors studied.

Background data on segment length (in centerline miles) and lane expansions are also shown in Table 1. For each project, lane-miles of capacity were estimated by simply multiplying number of lanes by number of centerline miles. For example, the capacity of Project 15 increased from 15.6 lane miles (4 * 3.9) to 31.2 lane miles (8 * 3.9) when the 3.9-mile segment along Interstate-580 in Alameda County was expanded by one lane in each direction in 1986. In the data base, the number of lane miles for Project 15 was recorded as 15.6 for the period of 1980 to 1985 and 31.2 for the period of 1986 to 1994. Table 1 also shows the "variable name" used in the predictive models to account for each project's fixed effects (based on 0-1 coding). Fixed-effect variables help to capture the unique characteristics of certain places that are not expressed by other variables in an equation. Noland and Lem (2000) maintain that the inclusion of fixed-effect variables is absolutely essential in induced travel studies since so many exogenous, difficult-to-measure factors (e.g., entry of women into the workplace) have propelled VMT growth over the past several decades [see Heanue (1997) for further discussions].

Table 2 presents key variables used in conducting the path analysis, with variables organized across seven dimensions. Summary statistics for 360 data points (15 years of data pooled over 24 projects) are also shown. Over the 15-year study period, the 24 freeway segments constituted, on average, less than 3 percent of countywide VMT and lane-mile capacity. Office buildings constituted the highest average share (21 percent) of countywide

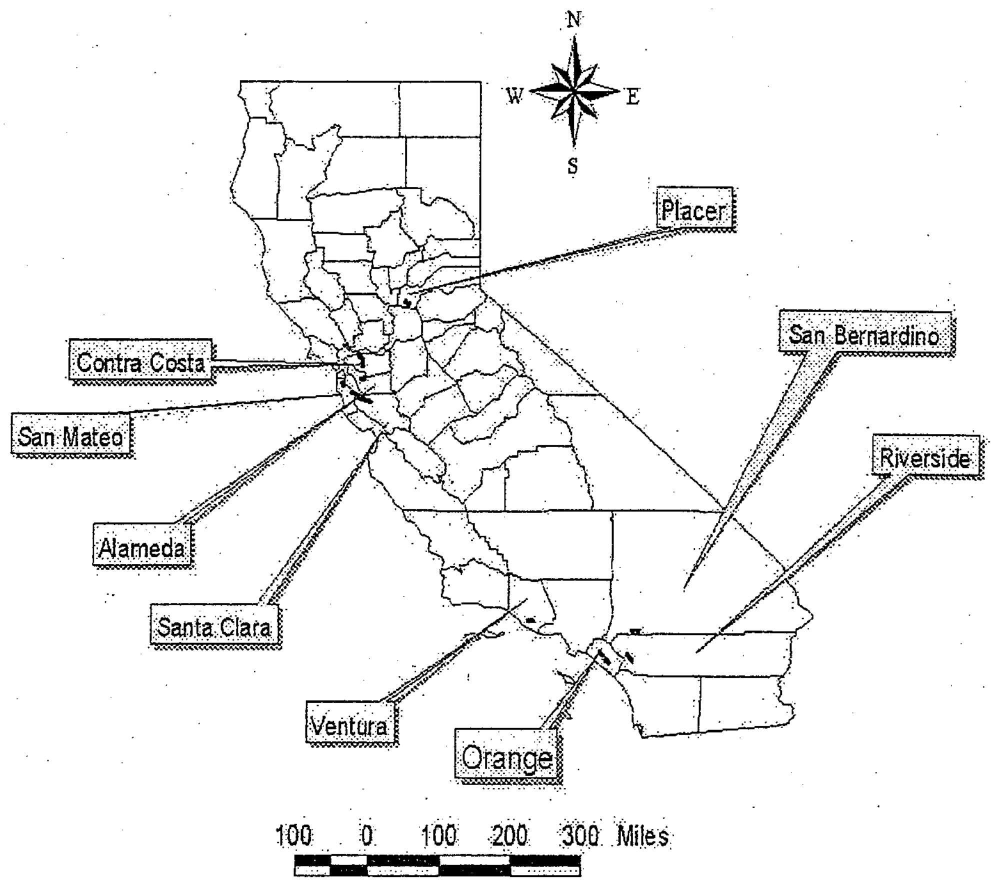
Table 1. Freeway Projects: Locations, Centerline Miles, Lane Expansions, and Variable Name

Project: Facility & County	Centerline Miles	Lane Expansion	Variable Name
1. Interstate-5, Orange County	4.9	8 to 10 lanes	Project1
2. Interstate-5, Orange County	2.6	8 to 16 lanes	Project2
3. Interstate-5, Orange County	2.7	6 to 10 lanes	Project3
4. Interstate-5, Orange County	2.1	6 to 14 lanes	Project4
5. Interstate-10, San Bernardino County	1.0	8 to 10 lanes	Project5
6. Interstate-15, Riverside County	3.6	4 to 6 lanes	Project6
7. U.S.-65, Placer County	3.5	2 to 4 lanes	Project7
8. U.S.-101, Ventura County	3.9	4 to 6 lanes	Project8
9. U.S.-101, Santa Clara County	1.3	6 to 8 lanes	Project9
10. U.S.-101, Santa Clara County	1.9	6 to 8 lanes	Project10
11. U.S.-101, Santa Clara County	1.2	6 to 8 lanes	Project11
12. U.S.-101, Santa Clara County	5.9	6 to 8 lanes	Project12
13. U.S.-101, Santa Clara County	6.4	6 to 8 lanes	Project13
14. U.S.-101, San Mateo County	5.4	6 to 8 lanes	Project14
15. Interstate-580, Alameda County	3.9	4 to 8 lanes	Project15
16. Interstate-580, Alameda County	2.1	4 to 8 lanes	Project16
17. Interstate-580, Alameda County	3.4	4 to 6 lanes	Project17
18. Interstate-680, Alameda County	2.8	4 to 8 lanes	Project18
19. Interstate-680, Contra Costa County	1.3	6 to 8 lanes	Project19
20. Interstate-680, Contra Costa County	1.2	6 to 7 lanes	Project20
21. Interstate-680, Contra Costa County	3.1	4 to 6 lanes	Project21
22. Interstate-680, Contra Costa County	2.7	4 to 6 lanes	Project22
23. Interstate-680, Contra Costa County	1.5	4 to 6 lanes	Project23
24. Interstate-680, Contra Costa County	1.8	4 to 6 lanes	Project24

land-use activities within the freeway buffers. Because study corridors were in suburban settings, gross densities tended to be fairly low for municipalities served by the freeways studied. Whites made up a majority of households among the freeway-served municipalities. Also, an appreciable share of households -- one out of six – was Hispanic.

5. Near-Term Path Model

The near-term model shown in Figure 1 postulates that the influences of freeway expansions on VMT are channeled through an intermediate step – operating speed. Only if speeds increase can traffic levels also be expected to rise, reflecting both newly generated trips (e.g., latent trips unleashed by faster moving traffic) and route diversions. And in due time, an equilibrium is reached as rising traffic volumes erode the travel-time savings, some trips are again suppressed, and motorists stop switching routes and modes.



Map 1. Location of 24 Freeway Projects Across Nine California Counties

Table 2. Key Endogenous and Predictor Variables: Summary Statistics and Data Sources

Dimension	Variable	Mean or Proportion	Std. Deviation
Demand	VMT on facility, proportion of countywide total[1]	0.028	0.019
Supply	Lane Miles on facility, proportion of countywide total[1]	0.021	0.011
Benefit	Operating speed on facility, mean mph[1]	38.1	7.5
Land Use	Total building activity[2], buffer proportion of countywide total[3]	0.093	0.111
	Single-family units, buffer proportion of countywide total[3]	0.022	0.057
	Multi-family units, buffer proportion of countywide total[3]	0.016	0.022
	Office valuation, buffer proportion of countywide total[3]	0.211	0.432
	Retail-commercial valuation, buffer proportion of countywide total[3]	0.073	0.137
	Industrial building square footage, buffer proportion of countywide total[3]	0.080	0.125
	Other building square footage, buffer proportion of countywide total[3]	0.010	0.045
Density	Population, persons per square mile, municipality[4]	1,308.5	842.3
	Employment, workers per square mile, municipality[4]	744.2	531.1
Policy	Air Quality, Maximum CO, one hour, parts per million, county[5]	14.17	4.78
Population	Personal Income, mean ($000), municipality[6]	20.605	5.199
	Race: White, proportion, municipality[6]	0.669	0.082
	Race: Black, proportion, muncipality[6]	0.067	0.051
	Race: Asian, proportion, municipality[6]	0.093	0.045
	Ethnicity: Hispanic, proportion, municipality[6]	0.166	0.057

Notes: 1 *Source:* California Department of Transportation, agency data files
2 Defined as weighted average of countywide proportions for six land-use categories, with weights for each category measured by the number of units (residential uses) or establishments (non-residential uses).
3 *Source:* U.S. Census Bureau, *Construction-Building Permits*, Residential Construction Branch, Manufacturing Construction Division, Building Permit Branch.
4 *Source:* California Department of Finance, agency data files
5 *Source:* California Air Resources Board, agency data files
6 *Source:* U.S. Department of Commerce, Bureau of Economic Analysis

Operating Speed Model

The left-hand side of Table 3 presents a best-fitting log-linear model that predicts operating speeds for any time period as a function of predictor variables for the same time period. The coefficients for all but the fixed-effect control variables represent point elasticities. Values of the endogenous variable "VMT proportion" were estimated using instrumental variables (consisting of all exogenous and fixed-effect variables used in the simultaneous predictions of "operating speed" and "VMT proportion"). The estimated model explained over two-thirds of the variation in operating speeds across the 360 pooled time series and cross-sectional observations.

The results clearly show that operating speeds increased in step with gains in the share of countywide lane-miles along the study corridors. On average, every 10 percent increase in a facility's share of countywide freeway lane mileage was associated with a 4.2 percent increase in mean operating speed on that facility. As hypothesized, rising travel eroded some of the speed benefits conferred by a road. Based on elasticity values, however, it appears that VMT increases were not totally offsetting – that is, the speed-enhancing benefits of freeway expansions exceeded the speed-eroding impacts of rising VMT.

Consistent with theory, Table 3 also shows that operating speeds tended to fall in higher density settings. Moreover, there appeared to be secular declines in average freeway speeds, reflected by the consistent negative signs of time-series fixed effect variables (relative to the prior-year suppressed categories of 1980 and 1981).

Induced Travel Model

The near-term model that predicted VMT shares as a function of mean operating speeds is shown in the left-hand column of Table 4. Two-stage least squares (2SLS) estimation was used to provide instrumental-variable estimates of the endogenous variable, "operating speed", to reduce possible simultaneous-equation biases.

Statistically significant and positive induced travel effects were found, though it is noted that the estimated elasticity of 0.238 is considerably smaller than elasticities estimated in previous county-level studies drawn from California experiences that used lane-miles as a direct predictor (e.g., Hansen, *et al.*, 1993; Hansen and Huang, 1996; Cervero and Hansen, 2001). It is also smaller than "induced demand" elasticities estimated using project-level data

Table 3. Operating Speed Model: Natural Logarithm of Mean Operating Speed on Freeway, 24 California Freeway Segments, 1980 to 1994; 2SLS Estimation; See Tables 1 and 2 for Variable Definitions

	NEAR-TERM MODEL			LONGER-TERM MODEL		
	Coefficient	Std. Error	Prob.	Coefficient	Std. Error	Prob.
Natural Log of:						
Lane Mile Proportion	0.418	0.033	0.000	0.385	0.085	0.000
VMT Proportion	-0.184	0.027	0.000	-0.165	0.078	0.036
Employment Density	-0.173	0.011	0.000	-0.173	0.016	0.000
Time-Series Fixed Effects:						
1982	-0.032	0.024	0.198	0.247	0.221	0.272
1983	-0.045	0.025	0.069	0.201	0.183	0.280
1985	-0.091	0.025	0.000	0.161	0.144	0.276
1986	-0.047	0.025	0.064	0.212	0.170	0.226
1987	-0.046	0.025	0.069	0.214	0.169	0.220
1988	-0.037	0.025	0.142	0.224	0.170	0.217
1989	-0.058	0.026	0.024	0.206	0.181	0.267
1990	-0.056	0.025	0.028	0.204	0.180	0.269
1991	-0.046	0.025	0.070	0.210	0.177	0.248
1992	-0.037	0.026	0.147	0.226	0.178	0.212
1993	-0.052	0.026	0.050	0.219	0.183	0.239
1994	-0.038	0.027	0.142	0.245	0.185	0.195
Project Fixed Effects:						
Project1	0.188	0.035	0.000	0.199	0.051	0.000
Project2	0.315	0.036	0.000	0.304	0.052	0.000
Project3	0.453	0.039	0.000	0.430	0.057	0.000
Project4	0.494	0.040	0.000	0.452	0.063	0.000
Project5	0.473	0.067	0.000	0.340	0.140	0.016
Project7	-0.219	0.039	0.000	-0.191	0.059	0.001
Project9	0.377	0.040	0.000	0.356	0.067	0.000
Project10	0.380	0.041	0.000	0.324	0.070	0.000
Project11	0.300	0.035	0.000	0.304	0.036	0.000
Project15	0.099	0.034	0.004	0.112	0.050	0.026
Project16	0.176	0.038	0.000	0.167	0.054	0.002
Project17	0.102	0.034	0.003	0.109	0.050	0.028
Project18	-0.071	0.031	0.021	-0.074	0.033	0.023
Project19	0.122	0.031	0.000	0.109	0.045	0.016
Project20	0.191	0.032	0.000	0.161	0.050	0.001
Project21	-0.117	0.029	0.000	-0.119	0.042	0.005
Project22	-0.126	0.030	0.000	-0.125	0.043	0.004
Constant	5.630	0.107	0.000	5.223	0.374	0.000
Summary Statistics						
No. of Cases		360			360	
F Statistic (prob.)		21.22 (.000)			9.47 (.000)	
R Square		.675			.632	

Table 4. *Induced Travel Model*: Natural Logarithm of Vehicle Miles Traveled on Freeway as a Proportion of Countywide VMT on State Freeway and Highway Facilities, 24 California Freeway Segments, 1980 to 1994; 2SLS Estimation; See Tables 1 and 2 for Variable Definitions

	NEAR-TERM MODEL			LONGER-TERM MODEL		
	Coefficient	Std. Error	Prob.	Coefficient	Std. Error	Prob.
Natural Log of:						
Operating Speed	0.238	0.083	0.004	0.637	0.374	0.089
Building Activity (T-2)	–	–	–	0.107	0.055	0.059
Building Activity (T-3)	–	–	–	0.065	0.034	0.064
Employment Density	0.394	0.149	0.009	–	–	–
Population Density	0.834	0.219	0.000	1.071	0.211	0.000
Black Proportion	-1.244	0.060	0.000	-0.631	0.114	0.000
Hispanic Proportion	–	–	–	-0.791	0.224	0.001
Time-Series Fixed Effects:						
1982	0.162	0.028	0.000	-0.038	0.012	0.000
1983	0.128	0.027	0.000	-0.040	0.015	0.000
1984	0.108	0.029	0.000	-0.095	0.039	0.018
1985	0.092	0.026	0.000	-0.075	0.048	0.121
1986	0.046	0.026	0.074	-0.063	0.032	0.049
1987	-0.034	0.026	0.193	-0.117	0.033	0.000
1988	-0.035	0.026	0.175	-0.067	0.030	0.028
1989	-0.036	0.026	0.169	-0.054	0.031	0.079
1990	0.016	0.008	0.058	0.017	0.009	0.060
1991	0.054	0.026	0.038	0.079	0.035	0.025
Project Fixed Effects:						
Project1	-2.809	0.143	0.000	-0.831	0.283	0.004
Project2	-3.220	0.144	0.000	-1.288	0.295	0.000
Project3	-3.571	0.144	0.000	-1.695	0.314	0.000
Project4	-3.577	0.143	0.000	-1.681	0.300	0.000
Project5	2.089	0.238	0.000	2.307	0.671	0.001
Project6	2.347	0.167	0.000	2.846	0.418	0.000
Project7	-1.020	0.180	0.000	-1.051	0.179	0.000
Project8	0.705	0.093	0.000	2.048	0.227	0.000
Project9	-1.708	0.042	0.000	-0.423	0.047	0.000
Project10	-1.733	0.042	0.000	-0.459	0.047	0.000
Project11	-1.303	0.043	0.000	-1.205	0.039	0.000
Project12	0.068	0.042	0.108	1.208	0.047	0.000
Project14	0.482	0.042	0.000	1.230	0.072	0.000
Project15	0.485	0.067	0.000	0.398	0.082	0.000
Project16	-0.120	0.066	0.069	-0.179	0.063	0.005
Project17	0.377	0.066	0.000	0.298	0.071	0.000
Project18	0.937	0.039	0.021	0.968	0.054	0.000
Project19	0.304	0.038	0.000	0.183	0.059	0.002
Project20	0.386	0.038	0.000	0.398	0.051	0.000
Project21	1.178	0.037	0.000	1.272	0.043	0.000
Project22	0.678	0.037	0.000	0.716	0.042	0.004
Constant	-16.257	0.837	0.000	-17.143	3.244	0.000
Summary Statistics						
No. of Cases	360			360		
F Statistic (prob.)	339.99 (.000)			257.00 (.000)		
R Square	.971			.973		

(Pells, 1989; Hansen, *et al.*, 1993). The lower estimate supports the arguments of Cohen (1995), DeCorla-Souza (2000), Pickrell (2001), and others that lane-mile elasticities tend to overstate induced demand effects.

Signs for the other major predictor variables used in the model generally match *a priori* expectations. The proportion of countywide VMT along a freeway tended to increase where the population and employment densities of municipalities traversed or flanked by the freeway were comparatively high. The racial composition of a corridor (likely reflecting income and possibly cultural factors) also tended to have some bearing on traffic volumes, all else being equal.

Short-Run Model Summary

Overall, the short-term path model postulated in Figure 1 was confirmed by the empirical results. Notably, added capacity increases speeds, which in turn raises the countywide share of traffic, which then erodes some of the speed benefits, thereby moderating the growth in traffic until more or less an equilibrium condition is reached. Based on California experiences along 24 freeway corridors over the 1980 to 1994 period, a near-term "induced travel" elasticity of 0.24 was estimated. In that some of this travel increase represents route diversions, the "induced demand" elasticity of newly produced VMT is likely even smaller. These results, which are more in line with those of several recent disaggregate, person-level studies of induced demand (Strathman, *et al.*, 2000; Barr, 2000), suggest that past estimates of induced demand derived from lane-mile elasticities have overstated near-term impacts.

6. Longer-Term Path Model

The results of subjecting the longer-term path model to empirical scrutiny are summarized in Tables 3 through 7. Current VMT is treated as a product of both immediate- and delayed-response influences, the former consisting mainly of behavior shifts (i.e., latent trips, route diversion) and the latter comprising structural adjustments (i.e., land-use changes).

Operating Speed Model

From the right-hand side columns of Table 3, model outputs for predicting mean operating speeds paralleled those of the near-term model. Differences in coefficient estimates reflect the influences of a different (and larger) set of instrumental variables in the longer-term model. In the longer-term specification, the elasticity of operating speed as a function of relative road capacity and traffic levels was slightly smaller.

Induced Growth Model

The hypothesis of "induced growth" – i.e., road improvements and the resulting swifter travel speeds spur real-estate construction along a corridor -- was substantially confirmed. The model presented in Table 5 represents the lagged structure that yielded the best-fitting statistical results. The model, which explained around two-thirds of variation in total building activity as a share of countywide totals, reveals the presence of institutional delays, as postulated. Notably, the share of countywide building square footage and valuations along a corridor increased with the share of countywide freeway lane-mileage added three years earlier. Building activities were also highly responsive to average operating speeds two years before. Evidently, lane-mile additions in previous years, confirmed by increased operating speeds, spurred developers to build more housing, offices, shops, and other establishments within several miles of improved freeways. Based on elasticity estimates, the influences of operating speeds on the decision to build were more than twice as great as the influences of lane-mile additions. Far more important than either factor was the control variable "personal income". All things being equal, growth among the California municipalities studied tended to gravitate to areas with relatively high incomes.

As noted, a composite variable was created to represent "building activities" within the two-mile buffers. While this variable proved to be statistically robust, it masked the relative influences of capacity expansions and speed improvements on development activities for specific land uses. To shed light on which uses were most sensitive to road improvements, individual OLS regression models were also estimated that predicted the shares of countywide units, valuations, or building square footage within freeway impact zones for specific land uses. The same variables considered in estimating the best-fitting "building activity" model were candidates for entry into each of the specific land-use models.

Table 5. *Induced Growth Model*: Natural Logarithm of Building Activity in Two-Mile Buffer as a Proportion of Countywide Building Activity, 24 California Freeway Segments, 1980 to 1994; OLS Estimation; See Tables 1 and 2 for Variable Definitions

	Coefficient	Std. Error	Prob.
Natural Log of:			
Lane Miles Proportion (T-3)	0.443	0.137	0.001
Operating Speed (T-2)	1.052	0.267	0.000
Personal Income	1.655	0.259	0.000
Time-Series Fixed Effects:			
1985	-0.430	0.280	0.125
1986	-1.113	0.297	0.000
1987	-1.485	0.322	0.000
1988	-2.295	0.380	0.000
1989	-2.848	0.416	0.000
1990	-3.375	0.460	0.000
1991	-4.176	0.470	0.000
1992	-4.518	0.499	0.000
1993	-5.771	0.513	0.000
1994	-4.889	0.551	0.000
Project Fixed Effects:			
Project1	-0.864	0.321	0.008
Project2	-0.518	0.313	0.098
Project4	0.557	0.335	0.096
Project5	3.891	0.558	0.000
Project7	2.957	0.339	0.000
Project8	1.403	0.348	0.000
Project15	-2.278	0.340	0.000
Project16	-0.853	0.351	0.016
Project17	-0.806	0.344	0.020
Project18	-0.884	0.328	0.008
Project19	1.765	0.317	0.000
Constant	-77.261	11.313	0.000
Summary Statistics			
No. of Cases		360	
F Statistic (prob.)		21.90 (.000)	
R Square		.666	

Table 6 presents elasticities for designated time-lag periods for the path model's two key predictor variables – lane miles and operating speed. Overall, development seemed to be fairly sensitive to freeway improvements across all six land-use categories. Home-building was most responsive. Lane-mile additions two to four years previously, and in the case of apartments and multi-family units, operating speeds two years earlier, significantly explained residential construction, with elasticity estimates well above one. Barring restrictive zoning or Not-in-my-Backyard (NIMBY) resistance, housing developers clearly reacted to capacity expansions along most of the freeway corridors studied. The opening of new lanes and the ensuing higher travel speeds appear to have prompted housing developers to draft plans and seek building permits, with actual housing additions occurring several years later.

Non-residential activities were most responsive to changes in operating speeds two to four years previously, with lane-mile additions three to four years earlier exerting more modest effects on office, industrial, and public-use construction. Consistent with theories of "highest and best use", offices and public buildings appeared to value accessibility benefits conferred by freeway expansions more than industrial uses. These results square with the finding of Hansen, *et al.* (1993) that from 1966 to 1989, commercial-office construction in California urban areas was more sensitive to freeway expansions than were other types of land uses. Table 5 also shows that prior-year operating speeds, but not lane-mile additions, spurred retail development. The lower elasticity could reflect the relatively higher premium many retailers place on visibility and exposure to pass-by traffic, regardless of the operating speeds, rather than on roadway capacity *per se* (see, for example, Bonsignore and Roach, 1992).

Induced Travel Model

Table 4 also provides elasticity estimates of "induced travel" over a longer-term time horizon, which consistent with theory and past research are higher than short-run effects. Still, the longer-run elasticity estimate of 0.637 is smaller in absolute terms than elasticities estimated in previous studies that used lane miles as direct predictors (Hansen, *et al.*, 1993; Hansen and Huang, 1997; Noland and Cowart, 2000; Cervero and Hansen, 2001).

Table 6. Summary Elasticities of Building Activities as Functions of Predictor Variables on Lane Miles and Operating Speeds, and Model Goodness-of-Fit Statistic. All variables expressed in natural log form, thus coefficients denote elasticities. See Tables 1 and 2 for definitions of variables.

Building Activity Dependent Variable:	Key Predictor Variables (in natural log form)				R Square
	Lane Miles		Operating Speed		
	No. Years Lagged	Coefficient	No. Years Lagged	Coefficient	
Residential:					
Single-Family[1]	2	1.311***	–	–	0.804
Multi-Family[2]	4	1.252**	2	1.260***	0.747
Non-Residential:					
Office[3]	3	0.655*	3	0.916*	0.638
Retail[4]	–	–	4	0.544*	0.566
Industrial[5]	3	0.405*	2	0.762*	0.708
Other[6]	4	0.576*	2	0.900*	0.533

Key:

*** = Significant at the 0.01 probability level

** = Significant at the 0.05 probability level

* = Significant at the 0.01 probability level

1 = Other predictor variables in the model: Time Series: 1984-1997; Project7 through Project15; Project 18.

2 = Other predictor variables in the model: Time Series: 1996-1997; Project1 through Project4; Project 6 through Project9; Project12; Project13; Project18 through Project21.

3 = Other predictor variables in the model: Natural logs of Personal Income, Population Density, and Asian Proportion; Time Series: 1983 through 1993; Project1 through Project4; Project7 through Project19.

4 = Other predictor variables in the model: Natural logs of Personal Income, Population Density, White Proportion, and Asian Proportion; Times Series: 1985 through 1994; Project1; Project2; Project5 through Project11; Project14; Project16 through Project19; Project21.

5 = Other predictor variables in the model: Natural log of Employment Density; Time Series: 1983 through 1994; Project4 through Project11; Project14; Project15; Project18 through Project21.

6 = Other predictor variables in the model: Natural logs of Personal Income, Population Density, and Black Proportion; Time Series: 1984 through 1994; Project2; Project5 through Project15; Project18; Project19.

The longer-term model also reveals that a smaller but nonetheless appreciable increase in VMT is attributable to heightened development activity along impacted corridors. Notably, traffic generated by new residential and commercial-industrial-institutional development accounted for some of the VMT gains, with the additive elasticity for building activities two and three years previously estimated to be 0.172. The output suggests that the influences of behavioral shifts (e.g., latent trips, modal changes, route diversions) are nearly four times as strong as those of structural changes (e.g., land-use shifts).

While longer-run induced travel effects were corroborated by the model, it is worth noting that other "control" factors, such as population density and racial-economic attributes (presumably as proxies for income and cultural factors), tended to exert even stronger influences on VMT shares. All else being equal, dense corridors made up predominantly of non-black and non-Hispanic households tended to account for relatively high shares of countywide VMT.

Induced Investment Model

To bring the analysis of freeway demand-supply relationships full circle, a model was estimated on how road investments respond to traffic increases. Table 7 reveals a significant induced-investment effect. Every 10 percent increase in the share of countywide VMT on a corridor two years previously is associated with a 4.9 percent increase in the current share of countywide lane-mile capacity, *ceteris paribus*. While the induced-investment effect appears smaller than the induced-travel effect, the estimated elasticity is considerably larger than that estimated by Cervero and Hansen (2001) using countywide data from California over a similar time span. This finding further suggests an over-statement of induced demand effects from past studies. That is, a significant share of the statistical correlation between travel demand and road supply has long been assigned to induced demand effects; however, when a path-model framework is adopted that accounts for intermediate steps and induced investment effects, longer-run elasticities of VMT growth tend to be smaller, matched by higher "induced investment" elasticities.

Besides VMT levels, previous-year operating speeds were also statistically associated with freeway expansion. The fact that variables measuring both VMT and operating speeds appeared as direct and statistically significant predictors of freeway expansion could reflect

Table 7. *Induced Investment Model*: Natural Logarithm of Lane Miles of Freeway Capacity as a Proportion of Countywide Lane Miles of Capacity for State Freeways, 24 California Freeway Segments, 1980 to 1994; OLS Estimation; See Tables 1 and 2 for Variable Definitions

	Coefficient	Std. Error	Prob.
Natural Log of:			
VMT Proportion (T-2)	0.490	0.049	0.000
Operating Speed (T-2)	-0.425	0.084	0.000
Maximum CO Level	-0.316	0.042	0.000
Time-Series Fixed Effects:			
1982	-0.055	0.040	0.164
1983	-0.113	0.038	0.003
1984	-0.143	0.037	0.000
1985	-0.131	0.037	0.000
1986	-0.568	0.042	0.179
1987	-0.063	0.402	0.140
1988	-0.104	0.040	0.010
1989	-0.071	0.041	0.085
1990	-0.059	0.041	0.147
1991	-0.058	0.037	0.133
1992	-0.032	0.022	0.128
Project Fixed Effects:			
Project1	0.440	0.064	0.000
Project2	0.204	0.055	0.000
Project5	-1.643	0.082	0.000
Project6	0.289	0.070	0.000
Project7	0.138	0.081	0.091
Project8	-0.152	0.074	0.042
Project9	-0.427	0.053	0.000
Project10	-0.472	0.053	0.000
Project11	-0.243	0.050	0.000
Project12	0.417	0.080	0.000
Project13	0.434	0.085	0.000
Project14	0.240	0.088	0.007
Project15	0.257	0.052	0.000
Project17	0.190	0.051	0.000
Project18	0.432	0.065	0.000
Project20	-0.229	0.053	0.000
Project21	0.286	0.070	0.000
Constant	-2.917	0.353	0.000
Summary Statistics			
No. of Cases		360	
F Statistic (prob.)		217.20 (.000)	
R Square		.949	

the influences of multiple criteria in investment decisions – that is, a combination of both traffic growth and performance levels could have played into political decisions to expand freeway capacity. Table 7 also shows that concerns over air-quality may have deterred freeway expansion, possibly out of fear that freeway-induced growth would ultimately exacerbate air quality. This stands in contrast to research by Cervero and Hansen (2001) that found deterioration in air-quality tended to spur road investments in California under the premise that congestion relief ultimately produces cleaner air. The fact that these two studies were carried out using different grains of analysis – county-level data in the case of the Cervero and Hansen study versus project-level data for this current study – could partly explain the differences.

Longer-Term Model Summary

Overall, the longer-term model performed fairly well in accounting for VMT growth along sampled California freeway segments. Evidence of "induced travel", "induced growth", and "induced investment" was uncovered. Elasticity estimates of induced travel were lower than what was found in most previous studies, including those focused on California freeways.

The long-run model suggests that it takes around 5 to 6 years before the full-brunt of traffic increases spurred by land-use shifts to be felt. Based on model outputs, it generally takes 2 to 3 years for development activity to respond to the addition of lane miles, and another 3 years for VMT to respond to development activity. The model also suggests that VMT growth feeds back to influence freeway investments several years later. The entire lagged structure, then, covers a 7 to 8 year period.

Based on beta weights, about 55 percent of the association between freeway expansion and VMT growth was accounted for by the path model.[ii] Thus while the postulated path model was supported by empirical analysis, more research is needed in different settings and at different resolutions of analysis to further refine our understanding of the co-dependencies between road investments, land-use shifts, and induced travel – hopefully research that is firmly rooted in behavioral and economic theories, and that adopts a casual modeling framework.

7. Conclusion

In recent years, concerns over induced demand have seemingly paralyzed the ability to rationalize road development in the United States. "Build it and they will come" has become a rallying cry of environmentalists, New Urbanists, and many others opposed to "sprawl-inducing" freeways.

Fairly firm positions have been taken on the induced demand debate despite the methodological shortcomings of past research. Simple mode structures have often been used to reach the conclusion that road investments provide only ephemeral congestion relief, with most added road capacity absorbed by increases in traffic. The path model presented in this paper attempts to sort through the ways in which road improvements affect travel demand, and vice-versa. As with past research, evidence of induced demand, induced growth, and induced investment was uncovered. Roads and the prominent fixtures of America's landscape that they serve – e.g., big-box retail, edge cities, and corporate campuses – are clearly co-dependent. While the magnitude of induced growth effects found in this study is generally consistent with that of previous research, the magnitude of induced demand effects is generally less. To the degree the path model better captures causal relationships than previous studies, many past elasticity estimates are likely inflated. The contention that capacity additions are quickly absorbed by increases in traffic and that "you can't build yourself out of traffic congestion" might not hold in all settings. Houston is a case in point. Over the past 15 years when the city invested around a billion dollars annually in freeway improvements (see Dunphy, 1997), Houston has made greater headway in relieving traffic congestion than most of its U.S. counterparts (Shrank and Lomax, 2000).

The problems people associate with roads – congestion, air pollution, and the like – are not the fault of road investments *per se*. These problems stem mainly from the unborne externalities from the *use* of roads, new and old alike. They also stem from the absence of thoughtful and integrated land-use planning and growth management around new interchanges and along new corridors. While the induced demand phenomenon is important and not to be trivialized, far more energies need to go toward figuring out how to best invest and manage scarce transportation and land resources – e.g., should we be building more bus rapid transit systems, applying "value-pricing" on current carpool lanes, and more closely integrating transportation and land use, and if so, when, where, and under what conditions? Whether new roads are on balance beneficial to society cannot be informed by studies of induced demand, but rather only through a full accounting and weighing of social costs and benefits.

Critics of any and all highway investments, even those backed by credible benefit-cost analyses, should more carefully choose their battles. Energies might be better directed at curbing mis-pricing in the highway sector and managing land-use changes spawn by road investments.

References

Asher, H. 1983. *Causal Modeling*. Newbury Park, California: Sage Publications, University Paper Number 07-003.

Barr, L. 2000. Testing for the Significance of Induced Highway Travel Demand in Metropolitan Areas, *Transportation Research Record* (forthcoming).

Boarnet, M. and Chalermpong, S. 2001. New Highways, Urban Development, and Induced Travel. Washington, D.C.: Paper presented at the 80th Annual Meeting of the Transportation Research Board.

Bonsall, P. 1996. Can Induced Traffic Be Measured by Surveys? *Transportation* 23: 17-34.

Bonsignore and W. Roache. 1992. Trip Generation: Fast Food for Thought. *ITE Journal*, Vol. 62, No. 2, pp. 33-36.

Cervero, R. 2001. Induced Travel Demand: An Urban and Metropolitan Perspective. Washington, D.C.: Paper presented at the Conference on Working Together to Address Induced Demand, Eno Transportation Foundation and the U.S. Environmental Protection Agency.

Cervero, R. and Hansen, M. 2001. Road Supply-Demand Relationships: Sorting Out Causal Linkages. Washington, D.C.: Paper presented at the 80th Annual Meeting of the Transportation Research Board.

Cohen, H. 1995. Review of Empirical Studies on Induced Traffic. *Expanding Metropolitan Highways: Implications for Air Quality and Energy Use*. Washington, D.C.: National Academy Press, Transportation Research Board, Special Report 245, Appendix B, pp. 295-309.

Cohen, H. 2001. The Induced Demand Effect: Evidence from National Data. Washington, D.C.: Paper presented at the Conference on Working Together to Address Induced Demand, Eno Transportation Foundation and the U.S. Environmental Protection Agency.

DeCorla-Souza, P. 2000. Induced Highway Travel: Transportation Policy Implications for Congested Metropolitan Areas. *Transportation Quarterly* 54, 2: 13-30.

DeCorla-Souza, P. and Cohen, H. 1999. Estimating Induced Travel for Evaluation of Metropolitan Highway Expansion. *Transportation* 26: 249-262.

Downs, A. 1962. The Law of Peak-Hour Expressway Congestion. *Traffic Quarterly*, Vol. 16, pp. 393-409.

Downs, A. 1992. *Stuck in Traffic: Coping with Peak-Hour Traffic Congestion*. Washington, D.C.: The Brookings Institution.

Dunphy, R. 1997. *Moving Beyond Gridlock: Traffic and Development*. Washington, D.C.: The Urban Land Institute.

Fulton, L., Meszler, D., Noland, R., and Thomas, J. 2000. A Statistical Analysis of Induced Travel Effects in the U.S. Mid-Atlantic Region, *Journal of Transportation and Statistics* 3, 1: 1-14.
Goodwin, P. 1996. Empirical Evidence on Induced Traffic: A Review and Synthesis, *Transportation* 23: 35-54.

Hansen, M., Gillen, D., Dobbins, A., Huang, Y., and Puvathingal, M. 1993. *The Air Quality Impacts of Urban Highway Capacity Expansion: Traffic Generation and Land Use Change*. Berkeley: University of California, Institute of Transportation Studies, Research Report 93-5.

Hansen, M. and Huang, Y. 1997. Road Supply and Traffic in Urban Areas: A Panel Study, *Transportation Research*, Vol. 31A, pp. 205-218.

Hartgen, D. and Kim, J. 1998. Commercial Development at Rural and Small-Town Interstate Exits. *Transportation Research Record*, Vol. 1659, pp. 95-104.

Hartgen, D. and Curley, D. 1999. *Beltways: Boon, Bane, or Blip? Factors Influencing Changes in Urbanized Area Traffic, 1990-1997*. Charlotte: University of North Carolina at Charlotte, Center for Interdisciplinary Transportation Studies, Transportation Publication Number 190.

Heanue, K. 1997. Highway Capacity and Induced Travel: Issues, Evidence and Implications. *Transportation Research Circular*, Vol. 418, pp. 33-45.

Hills, P. 1996. What is Induced Traffic? *Transportation* , Vol. 23, pp. 5-16.

Lee, D., Klein, L., and Camus, G. 1999. Induced Traffic and Induced Demand. *Transportation Research Record* , Vol. 1659, pp. 68-75.

Noland, R. and Cowart, W. 2000. Analysis of Metropolitan Highway Capacity and the Growth in Vehicle Miles of Travel. Washington, D.C.: Paper presented at the 79th Annual Meeting of the Transportation Research Board.

Noland, R. and Lem, L. 2000. Induced Travel: A Review of Recent Literature and the Implications for Transportation and Environmental Policy. Atlanta, Georgia: Paper presented at the Annual Conference of the American Collegiate Schools of Planning.

Pells, S. 1989. *User Response to New Road Capacity: A Review of Published Evidence*. Yorkshire, England: Institute of Transport Studies, The University of Leeds, Working Paper 283.

Pickrell, D. 2001. Induced Demand: Its Definition, Measurement, and Significance. Washington, D.C.: Paper presented at the Conference on Working Together to Address Induced Demand, Eno Transportation Foundation and the U.S. Environmental Protection Agency.

Shrank, D. and Lomax, T. 2000. *1999 Annual Mobility Report*. College Park, Texas: Texas Transportation Institute, Texas A&M University.

Strathman, J., Dueker, J., Sanchez, T., Zhang, J., and Riis, A. 2000. Analysis of Induced Travel in the 1995 NPTS. Washington, D.C.: U.S. Environmental Protection Agency, Office of Transportation and Air Quality, final technical report.

Surface Transportation Policy Project. 1998. *An Analysis of the Relationships Between Highway Expansion and Congestion in Metropolitan Areas*. Washington, D.C.: Surface Transportation Policy Project.

Urban Transportation Center. 1999. *Highways and Urban Decentralization*. Chicago: University of Illinois at Chicago, Urban Transportation Center, Research Report.

Voith, R. 1993. Changing Capitalization of CBD-Oriented Transportation Systems – Evidence from Philadelphia, 1970-1988. *Journal of Urban Economics*, Vol. 33, No. 3, pp. 361-376.

Notes

[i] Square footage statistics were already known from the census source for industrial and "other" land uses.

[ii] This was based on the application of "Wright's Rules" for decomposing correlation coefficients, as reviewed in Asher (1983). For the long-term model, the Pearson Product-Moment correlation between the natural logarithms of the "lane mile" variable and the "VMT" variable lagged by 5 years (to reflect the 2-year lag in lane-miles influencing building activities and the 3-year lag in building activities influencing VMT) was 0.898. If the model were completely specified, this correlation could be re-expressed as the sum of the products of beta weights (i.e., standardized regression coefficients) across all bona fide indirect paths. For the four indirect paths, the products of beta-weights are: Lane-miles → Speed → VMT [(1.294*0.265) = 0.342]; Lane-miles → Development Activity → VMT [(0.239*0.284) = 0.068]; Lane-miles → Speed → Development Activity → VMT [(1.294*0.218*0.284) = 0.080]; Lane-Mile → Speed → VMT → Speed → Development Activity → VMT [(1.294* 0.265* 0.337*0.218*0.284) = 0.007]. Thus, the total product of beta weights among indirect path equals 0.497, or 55 percent, of the total correlation of 0.898.

ATTACHMENT C

REALTY TIMES

March 31, 2003

NAR: Baby Boomer Investors Fueling Second Home Market Sales

Tne U.S. second home market is gearing up for what is virtually certain to be a series of record years for sales volume. But new research suggests that the buyers currently jumping into that market are strikingly different from buyers ɔ ely three years ago.

The new wave of second home purchasers--the leading edge of the baby boom demographic shock wave--are far more i estment-oriented than their predecessors, according to a new national study conducted by the National Association ɔt Realtors in conjunction with Escapehomes.com. Many more of them are buying to make money, not to spend weekends at the beach sipping margaritas.

Whereas just 20 percent of second home buyers in 1999-2000 had invesment returns as their primary motivation, nearly double (37 percent) of second home buyers last year ranked rental income as their primary objective. The study l ined "investment" properties as those rented out for an aggregate six or more months per year, and rarely if ever ised personally by their owners.

.ditional "non-investment" second homes, by contrast, are primarily purchased for personal use and only poradically rented out.

\ y the dramatic switch?

According to NAR economist Thomas Beers, the "slumping stock market" and the continuing high appreciation and ital gains from residential real estate have grabbed the attention of the baby boomers. While the Dow Jones index s off by 25 percent over the past three years and the Nasdaq down by 65 percent, Beers notes, residential proprty has een gaining value impressively. Nationwide, home values are up by an average 38 percent over the past 60 months l ie, according to the Office of Federal Housing Enterprise Oversight. But for many resort areas on the East and West coasts and in resort communities elsewhere, average gains have been even higher. Some well-located properties long the mid-Atlantic coast have doubled in resale value since 1997.

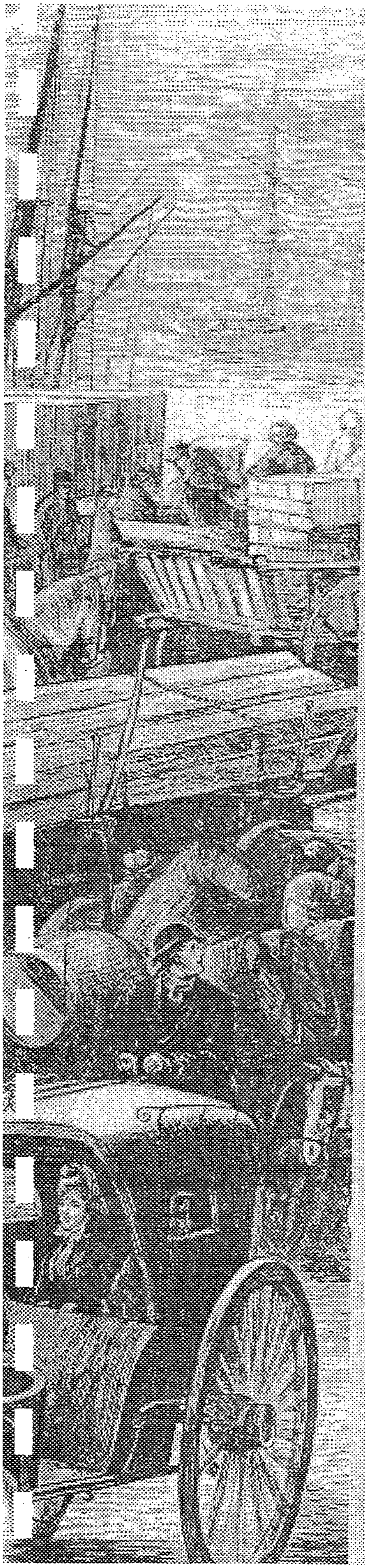
Who are the new, investment-minded baby boomers snapping up resort condos and homes? The NAR study of a ational statistical sample found that the typical purchaser is 56 years of age, married with no children living at home r er age 18, and is relatively affluent, with a household income of $92,000.

qually important: the baby boom shock wave is just getting started on second homes. Each year for the coming ade, according to NAR estimates, enough consumers will hit their mid-50s--the prime buying years for second omes--to expand construction in this sector by 150,000 units a year.

ey sub-trend documented by the study: Nearly 30 percent of all buyers expect to convert their second homes into ir primary homes sometime in the future. That move would provide a neat way to get maximum use of the federal 250,000/$500,000 tax-free capital gains exclusion.

example, a married couple in their mid-50s right now could buy a second home in a resort comunity, rent it out for ie next five to seven years, then sell their principal home tax-free, and convert the rental home to their new principal dence. That would start the tax clock ticking again on their resort residence, and allow them to pocket all gains on house tax-free (up to the $500,000 limit) after just 24 months of ownership and use.

ATTACHMENT D



CONTENTS

ACCESS No. 14 Spring 1999

The University of California Transportation Center, founded in 1988, facilitates research, education, and public service for the entire UC system. Activities have centered on the Berkeley, Davis, Irvine, Los Angeles, Riverside, and Santa Barbara campuses.

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Front Cover: Iron Oxide Magnified (2500X). Courtesy General Motors Research and Development Center.

The Land Use/Transportation Connection (cont'd)

BACK IN THE 1950s and 1960s, a basic aim for the newly proposed BART system was to curb urban sprawl. The trick was to reinforce major metropolitan centers and create new suburban subcenters. Because land adjacent to BART's station sites would be highly accessible, its planners expected they'd be powerful magnets attracting offices, shops, and high-density housing. Those concentrations would make for culturally enriched residential life and a more viable local economy. In turn, they'd attract riders to BART and thus help reduce traffic congestion.

Our mid-'70s assessments of promised land use effects were pessimistic, but probably premature, because land use changes are slow to show up. Now, some two decades later, it is possible to assess BART's influence on Bay Area development with greater precision and confidence.

John Landis and Robert Cervero have conducted a new series of land use studies around BART lines and stations, and they summarize their findings here. Their conclusions confirm those of the earlier assessment: Downtown San Francisco's office employment has indeed expanded dramatically near BART stations, but there has been only modest development around other stations—whether urban, suburban, or exurban. They find BART has had little influence on the location of either population or employment. Indeed, growth rates were lowest in those suburban corridors served by BART, and suburban office construction favored places that lack BART service.

Patronage has also fallen short of expectations. Initial forecasts expected 258,500 daily riders in 1975. Now, 24 years later and after a 30 percent increase in population, there may not yet be even that many riders on the original lines.

Metropolitan areas around the country have been building or extending rail systems and, with some notable exceptions, experiencing similarly disappointing patronage and urbanization effects. One exception is Washington's Metro, whose Orange Line route into Virginia is now a rapidly urbanizing corridor with a series of new, high-density subcenters surrounding stations. Although BART is several years older, nothing resembling such dense concentrations has emerged near its suburban stations (see photos on page 12).

Four explanations may account for the differences.

(1) At the outset, more auto ownership and an extensive network of highways and freeways endowed the Bay Area with a higher level of region-wide accessibility. The additional accessibility at BART stations was but a small increment and hence largely inconsequential.

(2) In the absence of numerous transit riders living or working at stations, these sites are less attractive to real-estate investors than are dispersed and spacious sites readily accessible by automobile.

(3) Unlike Metro's complex network of intracity lines, BART is essentially a suburban commuter railroad with two main lines reaching to outlying stations. Those stations are largely surrounded by paved lots offering free parking and occupying much of the adjacent land.

(4) As Jonathan Levine explains in his accompanying article, so long as land use regulations continue to limit locational choice for families and businesses, the land market can't respond to induce desired urban and travel patterns.

Suburban centers along Washington Metro's lines are direct products of active engagement by local governments collaborating with private land developers. Together, they changed land use regulations, exploited urban-redevelopment options, created joint-development enterprises, and forged tax and other financial incentives that encouraged high-density housing and high-rise office buildings. Metro thus became an effective instrument for city-building.

In contrast, it seems that BART saw itself primarily as a railroad rather than as an agent of urban development. So it didn't actively work with local governments to change the zoning, or with real-estate developers and financial institutions to build at stations. The absence of intensive suburban centers then translated into too few riders. In turn, BART's low patronage was little inducement to concentrated suburban development. In further turn, continued low density meant continued low patronage.

Our experience here suggests it's not enough just to install rail transit. It should now be apparent that we can't rely on trains alone to restructure the land market so that it spontaneously induces desired urban forms or attracts sufficient riders. Once again, events have exposed the intrinsic interdependencies between land use and transportation, showing that we can't treat the one without the other.

Melvin M. Webber

MIDDLE AGE SPRAWL: BART and Urban Development

BY JOHN LANDIS AND ROBERT CERVERO

BART was the first American rail rapid transit system to be built in modern times, and its arrival was greeted with worldwide attention. BART is famous. Its fame is attached to its favorable image as the answer to the problems of the modern American metropolis. And the extent to which it has succeeded, or failed, to live up to expectations is an important lesson for other cities wanting to emulate it.

BART is now middle-aged and certainly widely recognized as a part of the San Francisco Bay Area, but is it an important part? Do people in the Bay Area live and work in different locations and in different ways than they would if BART were not there? Can we point to housing projects, office buildings, shopping centers, or public buildings that would not have been built, or neighborhoods that would not have been revitalized but for BART's presence? Does BART provide more people with more accessibility to economic and social opportunities than they would otherwise enjoy? Would the Bay Area without BART be the same place it is today?

The answers to these questions may be more important today than in 1962, when BART's construction was approved by voters in Alameda, Contra Costa, and San Francisco counties. If, as many city planners and transit advocates believe, transit investments like BART can substantially alter metropolitan development patterns, then transit's role as "growth shaper" should be explicitly considered when making transit investment decisions. If, on the other hand, transit's effects on growth and urban form are only marginal, then decisions regarding transit investments should be primarily made either to relieve congestion or to enhance accessibility.

We wish here to summarize the results of a series of inquiries into BART's effects on Bay Area growth and urban form, undertaken as part of the BART@20 project. (Similar studies were undertaken in the mid-1970s as part of the initial BART Impact Study.) We review BART planners' initial expectations regarding the system's effects on the Bay Area and ask how transit investments influence urban development. We explore BART's effects on regional population and employment patterns, residential and office-construction activity near BART stations, the quality of BART's influence on land use change and redevelopment, and BART's effects on home prices, office rents, patronage, and retail sales volume.

John Landis and Robert Cervero are professors of city and regional planning at the University of California, Berkeley, CA 94720-1850 (jlandis@uclink.berkeley.edu and robertc@uclink.berkeley.edu). Research assistants on the BART@20 and related projects were Carlos Castellanos, Bruce Fukuji, Wicaksono Sarosa, Will Huang, Subrata Guhathakurta, David Loutzenheiser, Sourav Sen, and Ming Zhang.

INITIAL EXPECTATIONS AND PROCESSES OF CHANGE

Initial Expectations

The politicians, planners, and business and civic leaders who advocated building BART in the 1950s and 1960s did so expecting that BART would affect Bay Area development patterns in three related ways. First and foremost, BART would relieve mounting congestion problems on the Bay Bridge and major freeways, thereby insuring San Francisco's continuing dominance as the economic and political center of northern California.

Second, they hoped BART would serve as a structure for the inevitable outward suburbanization of the Bay Area. Rather than decentralizing willy-nilly, as Los Angeles was doing, the Bay Area would evolve into an efficient hierarchy of interdependent urban centers and subcenters, each specializing in some activity essential to the economic life of the region. Downtown San Francisco would stand at the apex of this hierarchy. One level down, Oakland and San Jose would serve as regional centers. One level further down were various subregional centers: Berkeley, San Mateo, Palo Alto, San Rafael, and Walnut Creek. BART would support this structure by linking these centers to each other and to suburban residential areas, creating points of high accessibility that would attract offices, high-density housing, and commerce. In doing so, BART would discourage leapfrog development and urban sprawl, which were regarded as economically and socially wasteful.

Third, BART would serve as a catalyst promoting redevelopment and reinvestment in older areas of Oakland, Berkeley, and Richmond, while promoting higher-density residential and mixed-use development in growing suburban jurisdictions. BART's success in meeting this last objective would depend on supportive land use and redevelopment policies at the local, neighborhood, and station-area levels. In the absence of such policies, BART's effects on the prospective built form of the Bay Area would be minimal.

Processes of Change

The processes through which transportation investments like BART affect urban development patterns are reasonably well understood. The principal effect of metropolitan transportation investments is to make previously distant sites more accessible, thereby adding to the supply of developable land within the metropolitan area. Able to purchase land more cheaply and still maintain their prior level of accessibility, households, stores, and businesses respond by moving outward. The resulting competition for suburban land causes site prices to rise above previous agricultural levels but below central city levels. If and when new agglomeration economies arise, usually among complementary land uses, land prices may increase further. Alternatively, rail transportation investments may serve to relieve congestion, ➢

thereby *maintaining* regional accessibility levels amidst continued growth.

Because accessibility is typically high near the sites of transportation facilities, rates of decentralization, land use change, and land price hikes should all be highest at the locations closest to the facility itself. For freeways, these high-value locations are at on-ramps, off-ramps, and interchanges; for rail transit systems, such as BART, they are at or near stations.

This simple theory lends itself to several testable propositions regarding BART's influence on Bay Area activity and development patterns. All else being equal:

- Activities requiring high levels of regional accessibility should concentrate around BART stations.
- To the extent that sites around BART stations are in limited supply, land prices, housing prices, and office rents near BART stations should be bid upward.
- Competition for sites around BART stations should cause development densities to increase.

POPULATION AND JOB GROWTH

As the foregoing suggests, one would expect population and employment growth to favor sites served by BART. To what extent has this actually been so?

Population Growth

Contrary to expectations, we found that population has grown faster away from BART than near it (Figure 1). The Metropolitan Transportation Commission divides the nine-county San Francisco Bay Area into 34 transportation planning superdistricts. In the twenty years since BART opened, population grew 35.2 percent in the 25 superdistricts not served by BART and only 17.1 percent in the nine BART-served superdistricts. In Alameda and Contra Costa counties, the population grew three to five times faster, in percentage terms, in areas not served by BART than in served areas.

Only in San Francisco was the pattern different. Population grew in the BART-served part of the city while the western half lost some four thousand residents.

FIGURE 1

Percent population growth in BART-served and non-BART-served superdistricts in Alameda, Contra Costa, and San Francisco counties: 1970–80, 1980–90

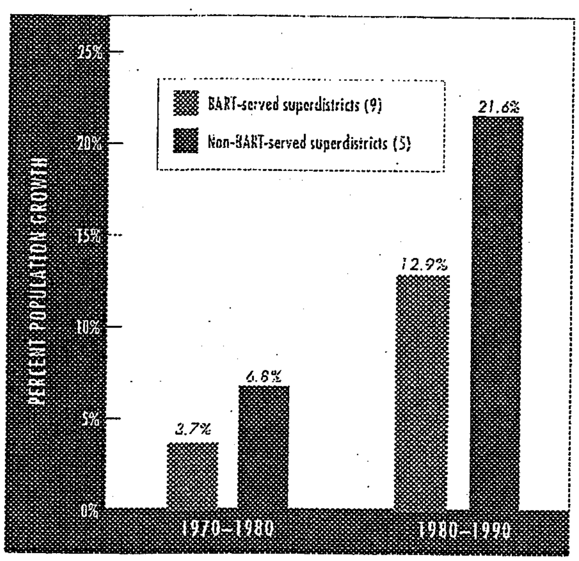
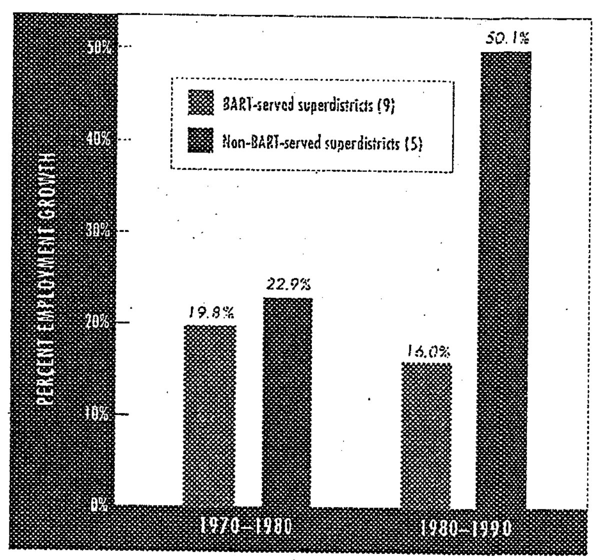


FIGURE 2

Percent employment growth in BART-served and non-BART-served superdistricts in Alameda, Contra Costa, and San Francisco counties: 1970–80, 1980–90



Employment Changes

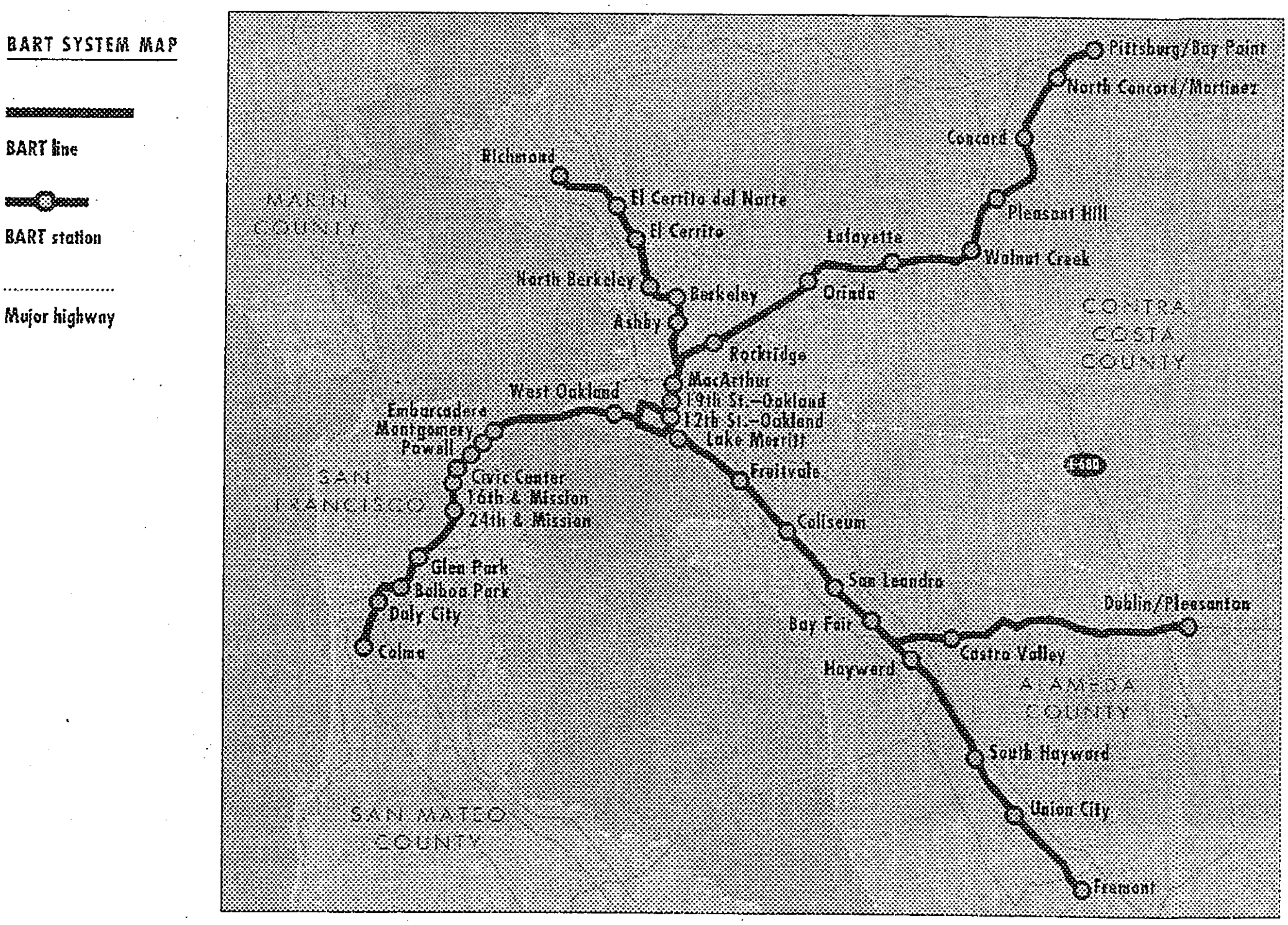
Outside San Francisco, a similar pattern emerged in employment changes (Figure 2). From 1970 to 1990, job growth mostly occurred away from BART. Employment grew 84.5 percent in non-BART superdistricts compared to 38.9 percent in the BART-served ones, mirroring the trend of job decentralization that was occurring throughout the U.S. At the county level, employment grew seven times faster in non-BART portions of Alameda County than in the BART-served portions, and non-BART superdistricts in Contra Costa County added jobs at twice the rate of BART-served areas. Growth percentages can sometimes be misleading: in absolute terms, 153,000 more jobs were created in BART-served superdistricts of Alameda and Contra Costa Counties than in the non-BART superdistricts.

A finer-grained analysis of employment growth by zip code showed marked disparities between San Francisco and the other counties for the 1980–90 period according to data at zip code level from *County Business Patterns.* The 35 zip codes in the three counties with BART stations gained 139,400 jobs from 1981 to 1990, growing by 30.3 percent and accounting for 57.1 percent of employment growth in the three counties. Employment in the 117 non-BART zip codes increased by 110,300, or 19 percent. However, almost all the BART-related employment growth occurred in San Francisco. Jobs in East Bay zip codes by comparison increased just 1.1 percent.

We also compared BART and non-BART employment growth differentials by business sector. The two sectors in which employment growth was most consistently concentrated in BART-served zip codes were Finance Insurance and Real Estate (FIRE), and non-Business Services. Even in these two sectors, however, employment growth was hardly uniform: it most favored BART-served zip codes in downtown San Francisco and along the north I-680 corridor.

In summary, job growth has been consistently higher around BART stations in downtown San Francisco than elsewhere in the region. In the East Bay, job growth has generally been faster away from BART, especially in the south I-680 corridor. ►

BART SYSTEM MAP



DEVELOPMENT ACTIVITY IN AND AROUND BART STATIONS

Residential Construction

We estimate that approximately four thousand housing units were demolished during construction of BART and related redevelopment projects. Once construction was completed, planners hoped these units would be replaced, and indeed, added to. But it didn't quite work out that way: disinvestment in housing near BART stations continued well after BART was completed. Between 1970 and 1990, housing units within a quarter-mile of BART stations declined by nearly four thousand units, or roughly −11 percent. In contrast, the number of housing units in BART-served cities grew by 20 percent, and Alameda, Contra Costa, and San Francisco counties together experienced a 25 percent increase. The loss of housing units around BART stations was mostly a downtown phenomenon in Berkeley, Oakland, and San Francisco (Figure 3).

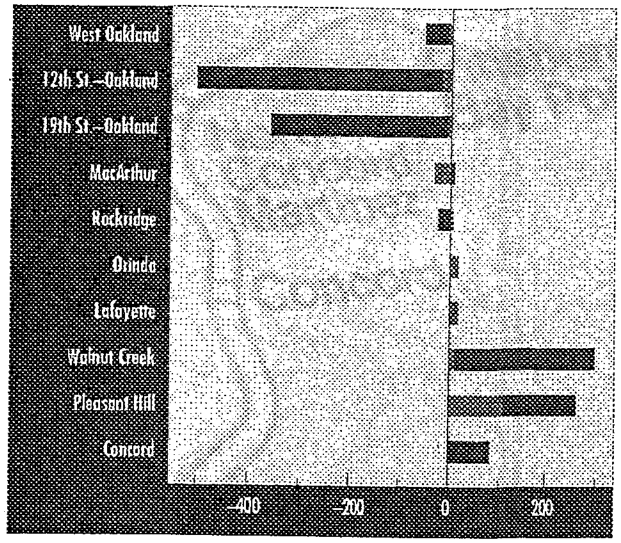
Additions to the housing stock, where they have occurred, have been concentrated at suburban stations, along the Fremont line, and near the end of the line. Most gains—as, indeed, most losses—have been apartment units. Property values and congestion levels near BART stations are generally too high, and neighborhood services and amenities too low, to attract single-family homebuilders.

FIGURE 3

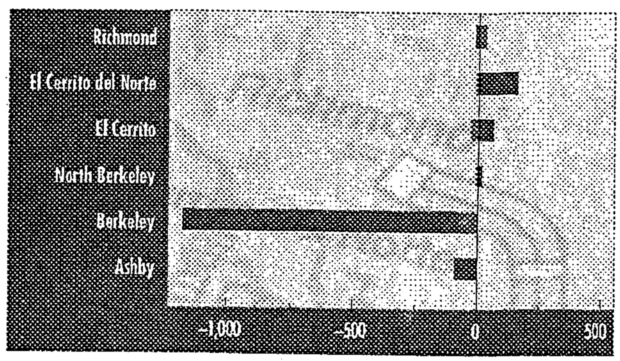
BART station areas: change in single- and multi-family housing units, 1970–1990

Change in single-family units
Change in multi-family units

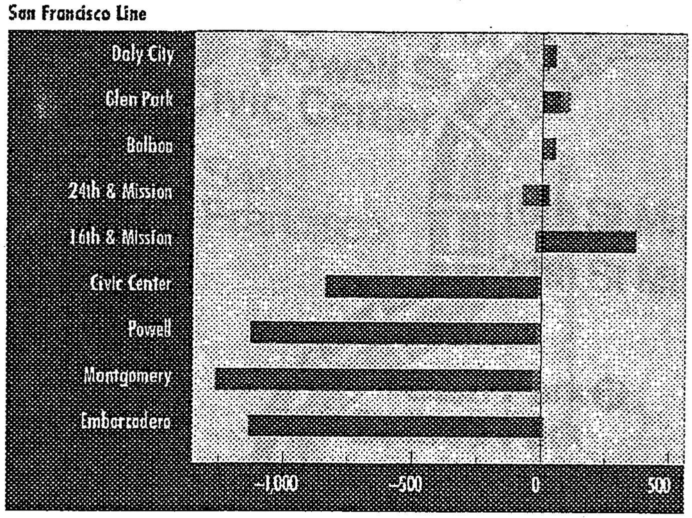
Concord Line



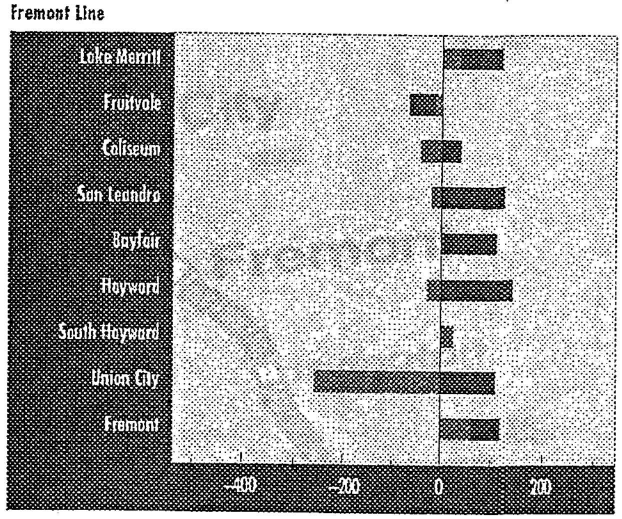
Richmond Line



San Francisco Line



Fremont Line



Just about everyone agrees that developing housing near BART stations is a good idea. In practice, it has always been a tough sell. Until recently, Bay Area apartment developers were more interested in suburban properties than older urban neighborhoods. Local general plans and development policies were—and to some extent, still are—indifferent to multi-family housing development. In addition, residents of established single-family neighborhoods around BART stations like North Berkeley and Rockridge have long opposed residential densification of any form. Except at a few isolated stations like Fremont, Pleasant Hill, and now Fruitvale and Castro Valley, opportunities for large-scale residential development have been sparse.

Thus, notwithstanding thirty years of demolition and construction, most near-BART housing is what it was and where it was two decades ago. In 1990, apartments comprised about three-quarters of the housing stock at BART station areas, about the same as in 1970.

Office Construction

In contrast to housing, BART has had a significant concentrating effect on office development, but only in San Francisco (Figure 4). In 1962—the year local funding for BART was approved by voters—the supply of office space in San Francisco stood at 18.8 million square feet. About half this total was located in the downtown area, within a quarter-mile of what would be ➢

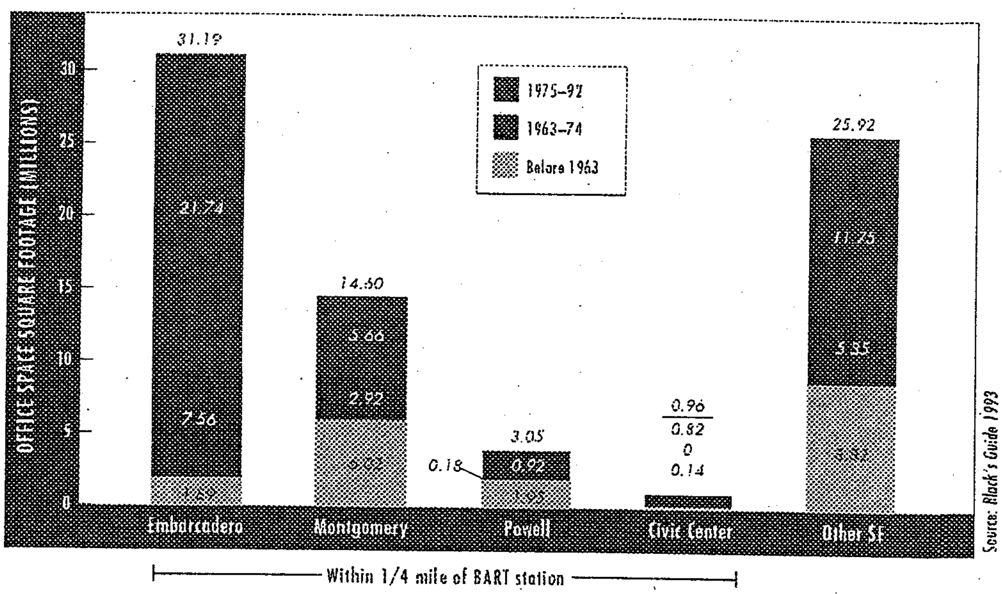
SOME HOUSING SUCCESS STORIES

There have been some notable exceptions to the tepid performance of housing around BART. BART's greatest housing success story is at the Pleasant Hill station, on the Concord line. Until 1988, the Pleasant Hill station was surrounded by a mix of modest single-family homes and open fields. Between 1988 and 1993, over 1,900 housing units were built within a quarter mile of the station—despite the station's being enveloped by BART's largest parking lot and lying in an unincorporated part of Contra Costa County. In many situations these conditions would have suppressed land development.

Three factors contributed to Pleasant Hill's turnaround. First, a cogent, specific plan created in the early 1980s served as a blueprint for guiding growth. Second, a proactive redevelopment authority aggressively sought to implement the plan by assembling irregular parcels into developable tracts, seeking out private co-ventures, and investing in supportive public infrastructure. Third, a local elected official became the project's political champion, working tirelessly and participating in numerous neighborhood meetings to shepherd the project through to implementation.

FIGURE 4

San Francisco office space construction by period



the locations of the Embarcadero, Montgomery, Powell, and Civic Center BART stations. Between 1963 and 1974, when BART was being built, San Francisco's office inventory expanded by 16 million square feet, two-thirds of which was located within a quarter mile of the same four BART stations. (Nearly half the office space built in downtown San Francisco between 1962 and 1974 was located close to the Embarcadero BART station.)

During the next eighteen years, another forty million square feet of office space—more than double what was already there—would be built in San Francisco. Nearly three-quarters of this amount would be built in downtown areas, within a quarter-mile of the downtown BART stations, and again with more than half the new supply near the Embarcadero BART station.

BART also facilitated development of larger office buildings. The average size of all San Francisco office buildings prior to 1962 was 72,000 square feet. The average size of office buildings constructed between 1963 and 1974 was 365,000 square feet for buildings located within a quarter-mile of future BART stations, but only 208,000 square feet for buildings located beyond the downtown area. As a result of public policies favoring smaller building footprints, office buildings constructed since 1975 have tended to be smaller than buildings constructed in the 1960s and early 1970s. This trend notwithstanding, the average size of new office buildings constructed since 1975 outside BART station areas is only 108,000, less than half the size of office buildings of a similar age located within a quarter-mile of a BART station.

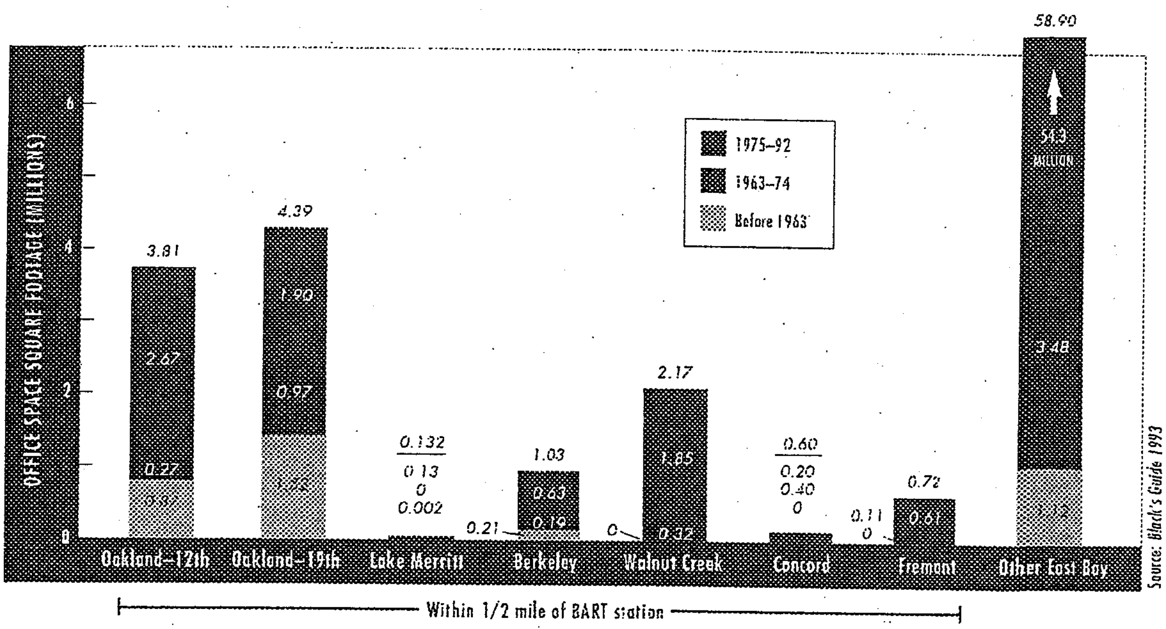
BART's concentrating influence on office development has not extended to the East Bay. In fact, as Figure 5 shows, East Bay office construction during the last thirty years has favored cities lacking BART service. As of 1962, the East Bay office inventory totaled about 3.7 million square feet. Of this total, about two-thirds was located within a half-mile of proposed BART stations in downtown Oakland, Berkeley, Walnut Creek, Concord, and Fremont. Of the 5.4 million square feet of new East Bay office space built between 1962 and 1974, only about a third was located within a half-mile of proposed BART stations. Of the sixty million square feet of new office space constructed in Alameda and Contra Costa counties between 1975 and 1992, only 15 percent was located within a quarter-mile of a BART station. Indeed, most of the new office space constructed in the East Bay since 1975 is located adjacent to freeway interchanges.

The Land Use Planning Connection

Why did BART help concentrate office development in San Francisco, but not in the East Bay? The answer to this question illustrates the crucial role of local planning and development policies in shaping the effects of transit on urban development. Remember that San Francisco political and business interests had always viewed BART's development as a tool for maintaining the city's regional primacy. The San Francisco Redevelopment Agency has long worked toward the same end. As part of its ongoing redevelopment efforts, it cleared vast amounts of land

FIGURE 5

East Bay office space construction by period



along the Embarcadero during the 1950s and 1960s. Large parcels suitable for modern office buildings were thus available for development right at what would become San Francisco's premier BART station.

More recently, San Francisco officials and citizens have adopted a succession of public policies aimed at concentrating office development in the downtown area and preventing its intrusion into residential neighborhoods. The first such policy was the Downtown Plan, adopted by the Board of Supervisors in 1985 and subsequently followed almost to the letter. The Downtown Plan was followed in 1986 by the passage of Proposition M, a citizen initiative limiting annual office construction to 400,000 square feet, thereby forcing office developers to compete for allotments. The ratings system adopted by the city for evaluating competing office development proposals strongly favors downtown locations. This has had the effect of making downtown sites even more valuable.

Taken together, these three policy initiatives: site clearance and land assembly, downtown-oriented commercial zoning (later augmented with development incentives), and the construction of a supporting transportation infrastructure (BART) have successfully prevented office development from decentralizing within San Francisco.

Ironically, these same policies helped to promote office decentralization outside of San Francisco. As downtown San Francisco office rents rose, partly in response to Proposition M construction caps and partly because of the inconvenience and high cost of development downtown, more and more office tenants began looking elsewhere in the region for office space. These tenants found cities with excess highway capacity, plentiful supplies of developable land, relatively liberal zoning and land use policies, and a yen to become a suburban office center. In the absence of a regional growth-coordinating agency, cities began competing with each other for commercial development.

Oakland, the one other city in the region well-positioned to use BART to catalyze downtown development, was unable to attract significant new office development. Instead, office developers and office tenants turned their attention to the Interstate 680 corridor in central Contra Costa County. The northern part of this corridor, the area between downtown Walnut Creek and downtown Concord, was served by BART. The southern part, from Danville to Pleasanton, was not. Except in downtown Walnut Creek—and even there, not until the mid-1980s—BART service was not a significant inducement to office developers.

BART AND OAKLAND

While BART has clearly helped downtown San Francisco maintain its economic vitality, its relationship with downtown Oakland is more complicated.

During BART's first ten years, virtually no new buildings were built around downtown Oakland's three stations. Things changed markedly since the early 1980s, thanks mainly to the construction of Oakland City Center, an ambitious office-retail complex built atop and linked to the 12th Street BART station that has received several design awards. Credit for City Center belongs jointly to the Oakland Redevelopment Agency, which provided a combination of land assemblage, tax increment financing of public infrastructure, securing federal urban renewal grants, subordination of loans, and equity participation (including majority ownership of a downtown convention hotel), and Bramalea-Pacific, a private development company that is headquartered in Toronto and thus familiar with transit-oriented downtown development.

Altogether, more than 1.6 million square feet of new office space (about 30 percent of the city's inventory) has been constructed in downtown Oakland since 1983. While this is certainly less than the volume of office space constructed in downtown San Francisco, it is probably more than would have been constructed in the absence of BART.

PATTERNS OF LAND USE CHANGE

Although BART has clearly had *some* localized influence on development activity at *some* stations, how far that influence extends and whether it has been systematic remain open questions. To gain a clearer understanding of BART's influence, we developed a series of statistical models of land use change in Alameda and Contra Costa counties between 1985 and 1995. (There were too few instances of land use change in San Francisco County.) The models track ten-year changes at the one-hectare (100m by 100m) site level.

We evaluated five types of undeveloped land use change and four types of redevelopment: no change in undeveloped land; change from undeveloped land to single-family residential use; change from undeveloped land to multi-family use; change from undeveloped land to commercial use; no change in developed land use; redevelopment from nonresidential to residential ►

The changing downtown San Francisco skyline, looking toward Embarcadero station. 1958

use; redevelopment from noncommercial development to commercial use; and redevelopment from nonindustrial development to industrial land use. These changes were compared with more than twenty predictive factors, such as the distance from each one-hectare site to the nearest BART station and freeway interchange. Altogether, more than 13,000 hectares of land in Alameda and Contra Costa counties changed use between 1985 and 1995.

BART's influence on 1985–95 land use change in the two counties turned out to be minor and uneven. In Alameda County, proximity to a BART station reduced the likelihood that a vacant site would be developed in either single-family use or commercial use and had no effect on multi-family or industrial development. In Contra Costa County, the closer a vacant site was to a BART station, the less likely it was to be developed in any use. BART's effect on redevelopment activity was even more varied. In Alameda County, proximity to a BART station increased the likelihood that a site would be redeveloped to commercial or industrial use, but not residential use. In Contra Costa County, proximity to a BART station had no effect on redevelopment.

BART's lack of influence stands in marked contrast to the effect of freeway interchanges. Among undeveloped Alameda and Contra Costa sites in 1985, proximity to the nearest freeway interchange exerted a strong negative effect on single-family development, a strong positive effect on commercial development, a strong positive effect on industrial development in Alameda County, and a weak negative effect on Contra Costa County industrial development. Proximity to a freeway interchange exerted a negative effect on residential redevelopment in Alameda County, a positive effect on Alameda County commercial redevelopment, and a negative effect on Contra Costa County industrial development.

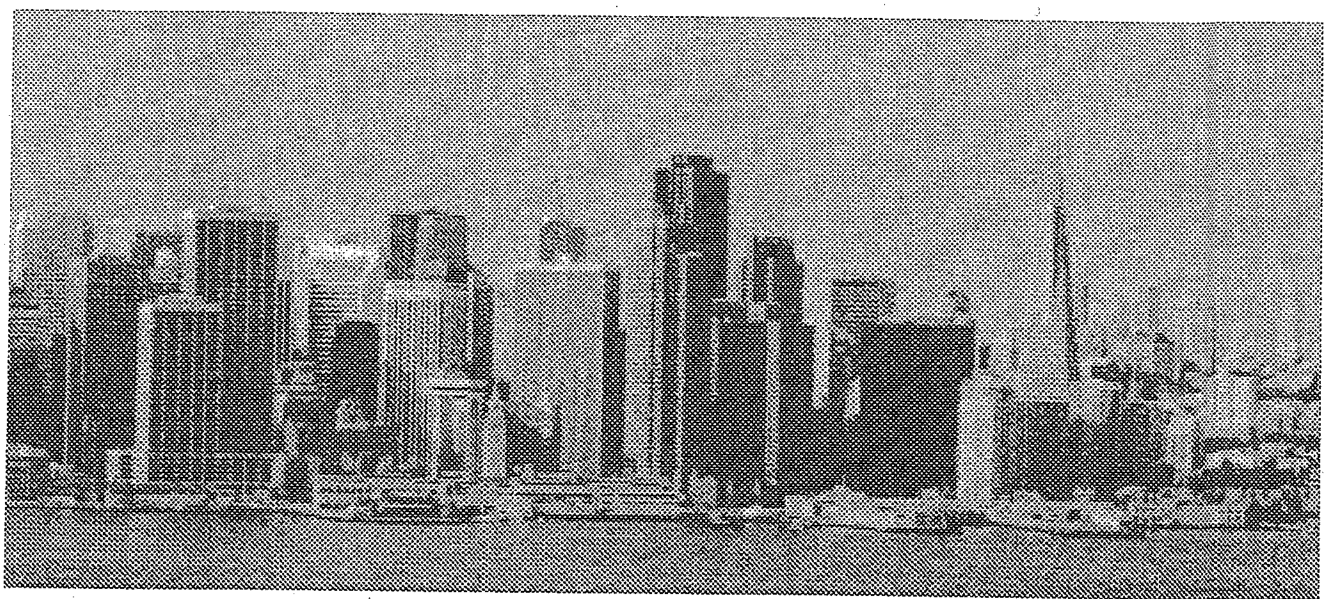
PRICE AND RENT EFFECTS

The process by which transportation investments influence property values is known as *capitalization.* To what extent has BART service been capitalized into residential property values and commercial rents?

BART and Housing Prices

Proximity to transit is only one of many possible factors affecting housing values. Others include the size, age, and structural characteristics of the individual house; the location of the house *vis-à-vis* regional employment and service centers; the quality of the neighborhood and neighborhood services (especially schools); and accessibility via automobile.

Proximity to any sort of transportation facility is a double-edged sword. On one hand, properties located near or adjacent to highways and rapid transit lines usually have excellent accessibility. On the other, homes located right next to major transportation facilities also suffer from noise, vibration, and, with highways, localized concentrations of pollution. Homes located away from transportation facilities can avoid such problems, but must sacrifice accessibility.



The photo at left is at the same scale as the one above.

1992

To test these propositions, we compared 1990 prices and characteristics among a sample of 2,360 home sales in Alameda and Contra Costa counties. We used a geographic information system (GIS) to address-match each transaction to its street address, and then measure its distance to the nearest BART station and the nearest freeway interchanges, and determine whether or not it was within 300 meters of an above-ground BART line or freeway.

All else being equal—that is, controlling for house size, age, number of bedrooms and bathrooms, income in 1989, neighborhood ethnic makeup, and being directly adjacent to a BART line or freeway—homes near BART stations in Alameda and Contra Costa counties sold at a premium, while homes near freeway interchanges sold at a discount.

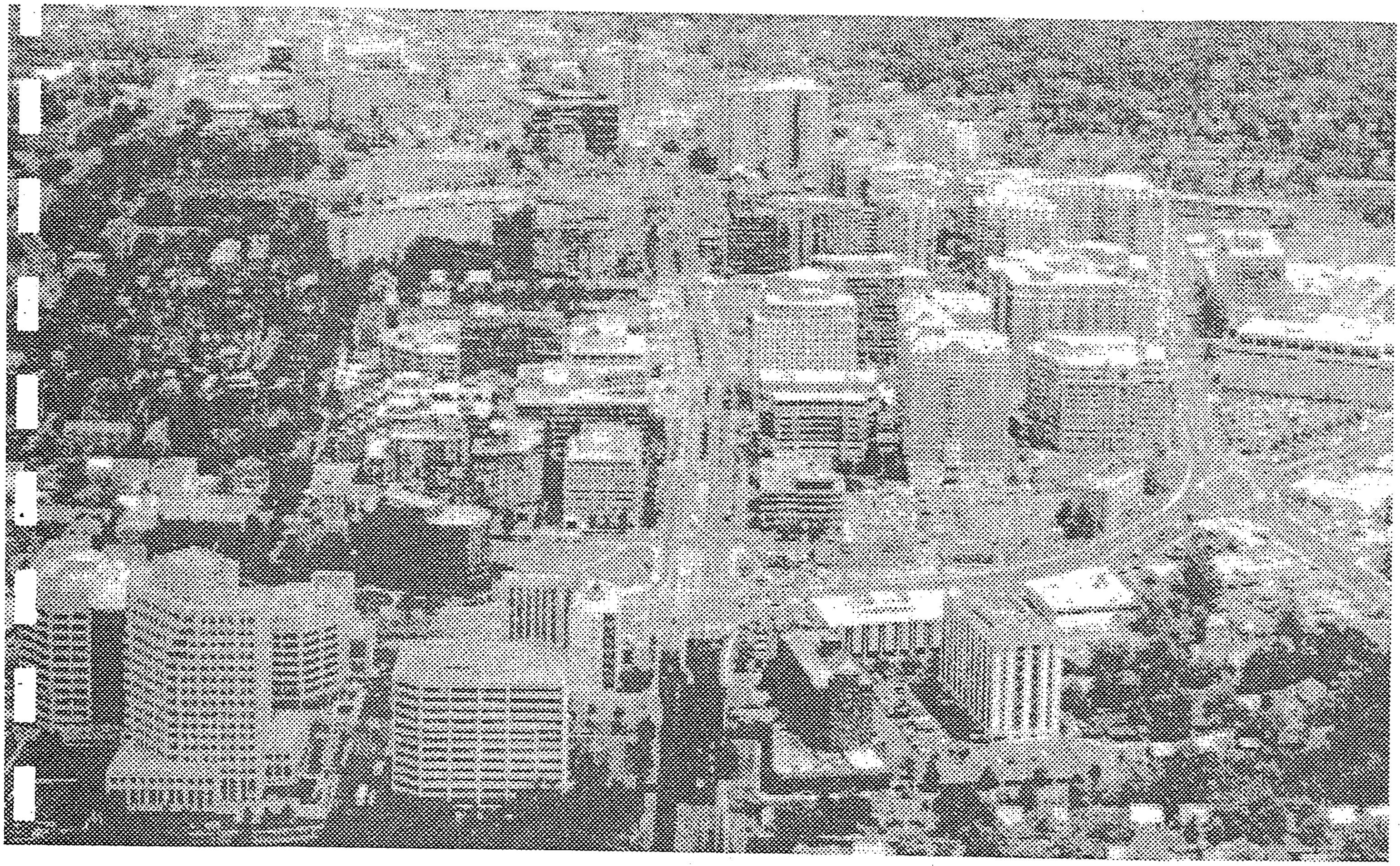
For every meter closer an Alameda county home was to the nearest BART station (measured along the street network), its 1990 sales price increased by $2.29. For Contra Costa homes that sold in 1990, the sales price premium associated with the nearest BART station was $1.96 per meter. The opposite effect held for freeway proximity: Alameda and Contra Costa homes near freeway interchanges sold for less than comparable homes elsewhere. For every meter it was closer to a freeway interchange, the 1990 sales price of an Alameda county home declined $2.80. The per meter discount associated with highway accessibility was even greater in Contra Costa County: $3.41.

These findings are subject to three caveats. First, as significant as they are, these transit premiums are not large enough by themselves to promote redevelopment or increased residential densities. Supportive land use policies and, where appropriate, subsidies and incentives, are also necessary to encourage residential upgrading. Second, the existence and magnitude of a station-access capitalization effect is by no means a sure thing. A similar analysis of houses near Sacramento and San Jose light-rail stations and San Mateo CalTrain stations failed to identify any such premiums.

Furthermore, the fact that a BART-access premium existed in the East Bay in 1990 does not mean that home values were correspondingly higher in every home in every neighborhood near a BART station. In neighborhoods suffering from weak housing demand, or where the quality of the housing stock is poor, there may well be no additional value associated with transit access.

BART and Office Rents

We used a similar approach to investigate the influence of BART service on office rents. We compared differences in 1993 office-building rents and vacancy rates in Alameda, Contra Costa, and San Francisco counties as a function of proximity to the nearest BART station. We culled listings for individual office buildings from *Black's Office Leasing Guide: 1993* (San Francisco Bay Area edition), and matched addresses to their appropriate street locations. BART proximity was measured using concentric rings of 1/8, 1/4, 3/8, and 1/2 mile around each BART station, except in downtown San Francisco, where it was measured using 1/8 and 1/4 mile rings only. ➻



A tale of two efforts to build suburban centers at suburban rail stations. Top, Ballston, Virginia, on the Washington Metro's Orange Line, one of several similar subcenters there. Bottom, Pleasant Hill, California, on BART's Concord Line, the largest new development at a previously greenfield station site.

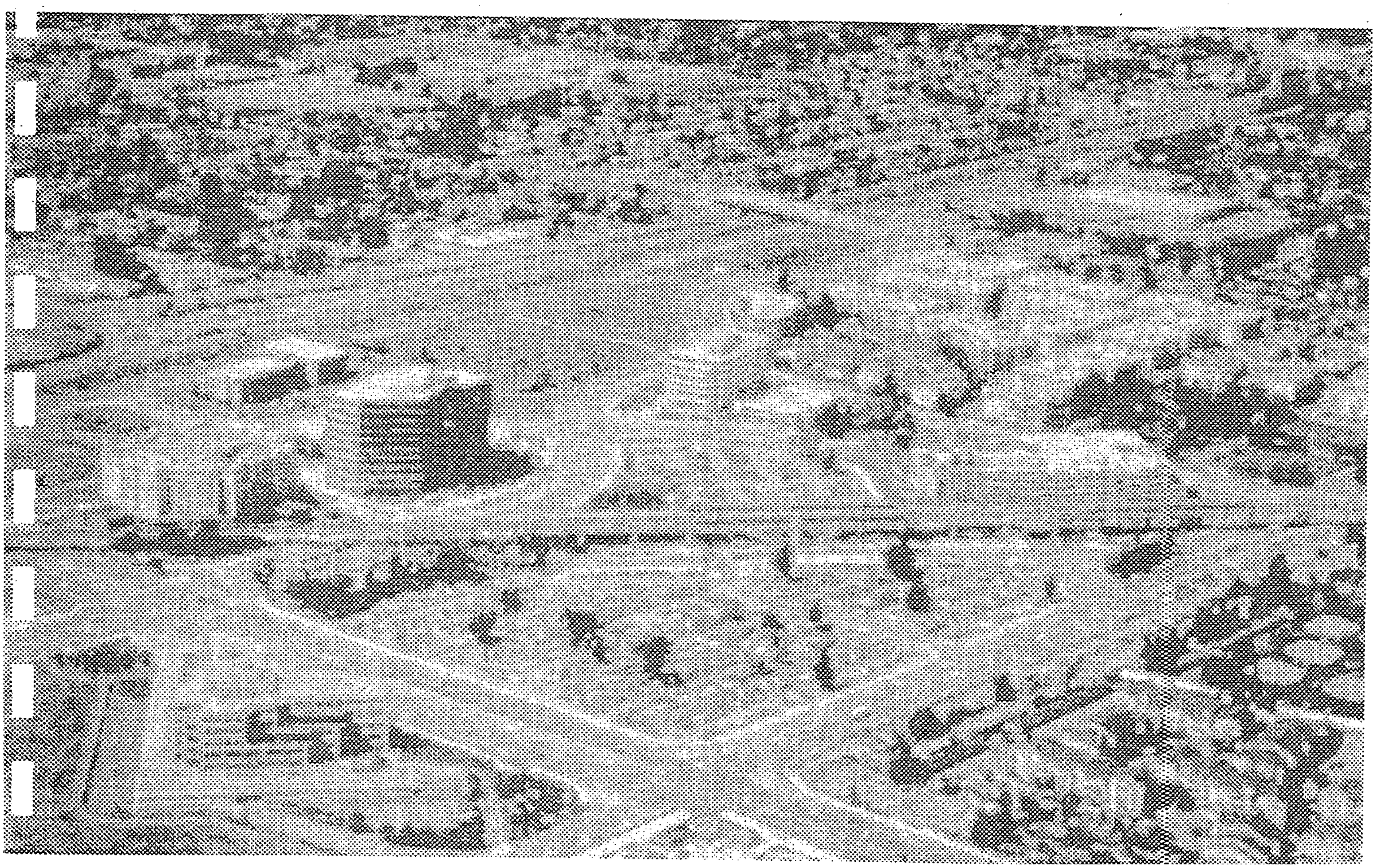
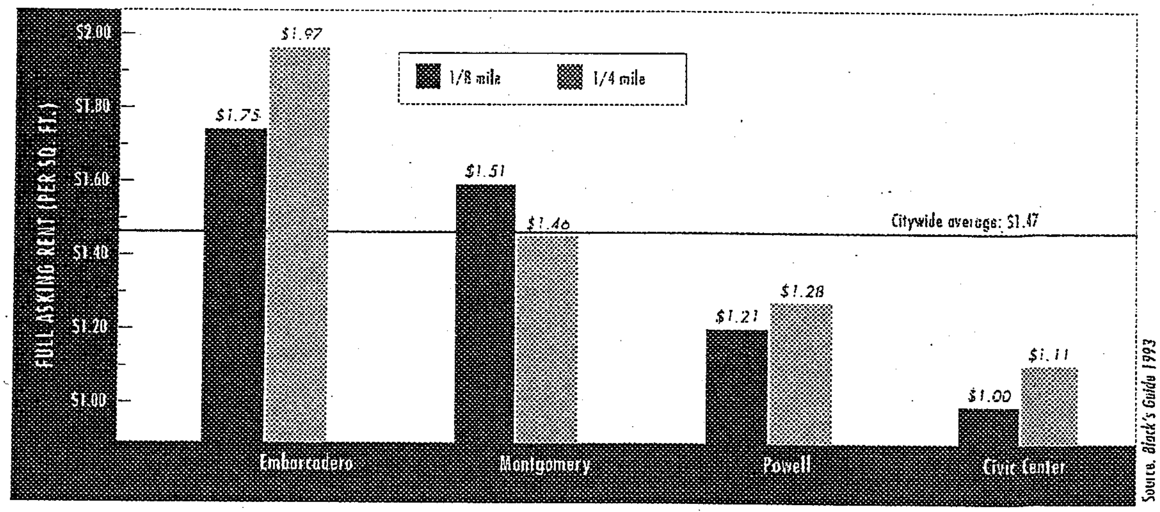


FIGURE 6

Average 1993 office rents in 1/8-mile distance rings from downtown San Francisco BART stations



If indeed office tenants do value accessibility to BART, then one would expect to find higher office rents for buildings closer to BART stations. Figure 6 shows that no such pattern is evident.

If proximity to BART makes a building more attractive to potential tenants, then one would also expect to find higher occupancy rates for buildings closer to BART stations. To a limited extent, this was indeed the case in 1993—especially for the two BART stations in San Francisco's financial district. When we looked more closely we found the higher occupancy levels associated with BART instead reflected improved building quality, not access to BART. These results confirm the observations of many commercial brokers: that office space is increasingly becoming a commodity and that rents follow the ever-changing balance of supply and demand and building characteristics more than location.

RETAIL ACTIVITY NEAR BART

BART was planned and constructed before the idea that transit stations should serve as neighborhood retail centers, or "transit villages," became as popular as it is today. Food is not allowed in BART stations or on BART trains, and no BART station includes significant internal retail space. Even at El Cerrito Plaza and Bayfair, the two BART stations which directly serve regional malls, station-shopping access is not as good as it could be.

These problems notwithstanding, there is a substantial amount of retail activity close to many BART stations. Major new retail projects have been developed adjacent to the Rockridge, Oakland-12th Street, El Cerrito del Norte, and Powell Street BART stations, and others are currently planned for the Fruitvale and Pleasant Hill BART stations.

How have the stores located at or near BART stations fared? Does being near a BART station boost customer traffic or sales? And are there any disadvantages to locating near a BART station?

Lacking area or retailer-specific information on retail sale volume, we developed and administered a brief questionnaire to all retailers located within a quarter-mile of twelve BART stations. The majority of respondents (54 percent) were long established at their current near-BART locations. Only 14 percent had been in business at their current (BART) locations for less than a year, while another 32 percent had been in business at their current locations for one to five years.

Close proximity to BART had been a very important consideration in their initial location decision, said 23 percent of respondents. Another 32 percent reported that BART proximity had been somewhat important. But an even larger number—45 percent—said that being near BART had not been a major consideration in their choice of location.

Opinions also varied widely regarding the contribution of BART to retail sales. Sample-wide, 14 percent of survey respondents believed BART contributed positively to their sales. Another 51 percent cited BART proximity as being only somewhat important to their business and sales, and one-third cited BART as having no effect. Furthermore, the longer retailers had been in business near BART, the less positively they viewed BART's contribution to sales.

Few weekday BART riders actually shop near BART stations—at least according to the survey respondents. Some 55 percent calculated that fewer than one in ten BART riders actually shopped at their stores. Only 7 percent thought that local BART riders comprised more than half their customer base. ▻

Restaurants and food stores were more likely to capture BART patrons than service businesses.

Forty-four percent of respondents cited customer and employee convenience as the primary advantage of being located near a BART station. Another 39 percent listed more customers as a major advantage. Greater visibility, additional pedestrian traffic, and BART's role as an area landmark were listed as major advantages by 20 percent, 15 percent, and 11 percent of respondents, respectively. Merchandise retailers perceived more advantages to being near BART than did restaurants, food stores, or service businesses.

On the other hand, almost a third of the survey respondents didn't list any disadvantages associated with being located near BART, although one-third cited the presence of "unwelcome people," and 22 percent cited reduced safety and security as key concerns. Merchandise retailers perceived more disadvantages from being located near BART than did other businesses—just as they also perceived more advantages. Retailers who had been in business a long time were neither more nor less likely to find specific faults than were retailers who had just opened up.

All in all, most respondents were happy with their locations. Sample-wide, 69 percent of respondents identified their current near-BART location as an ideal business location. Only 14 percent wanted to be located closer to a BART station, while only 10 percent preferred to be located farther away. Seven percent of respondents cited their ideal location as "nowhere near BART."

CONCLUSIONS

The story of BART and its effects on the metropolitan landscape of the Bay Area is complicated—composed of one very big achievement, several smaller successes, and many missed opportunities.

BART's major achievement has been to link downtown San Francisco with the growing suburbs of central Contra Costa County. This has allowed San Francisco to maintain its preeminence as the business and financial center of the Bay Area, even as regional auto use and traffic congestion have increased many times over. On a more modest scale, BART has helped spark new commercial and residential development around several suburban stations, most notably Walnut Creek, Pleasant Hill, Concord, and Fremont.

There have also been some notable failures. So far, BART has not triggered hoped-for levels of reinvestment in downtown Berkeley, Oakland, or Richmond. BART's land use effects on the Richmond and Fremont lines as a whole have been much less than were expected. Except for the Rockridge station in Oakland, BART has done little to encourage new retail development.

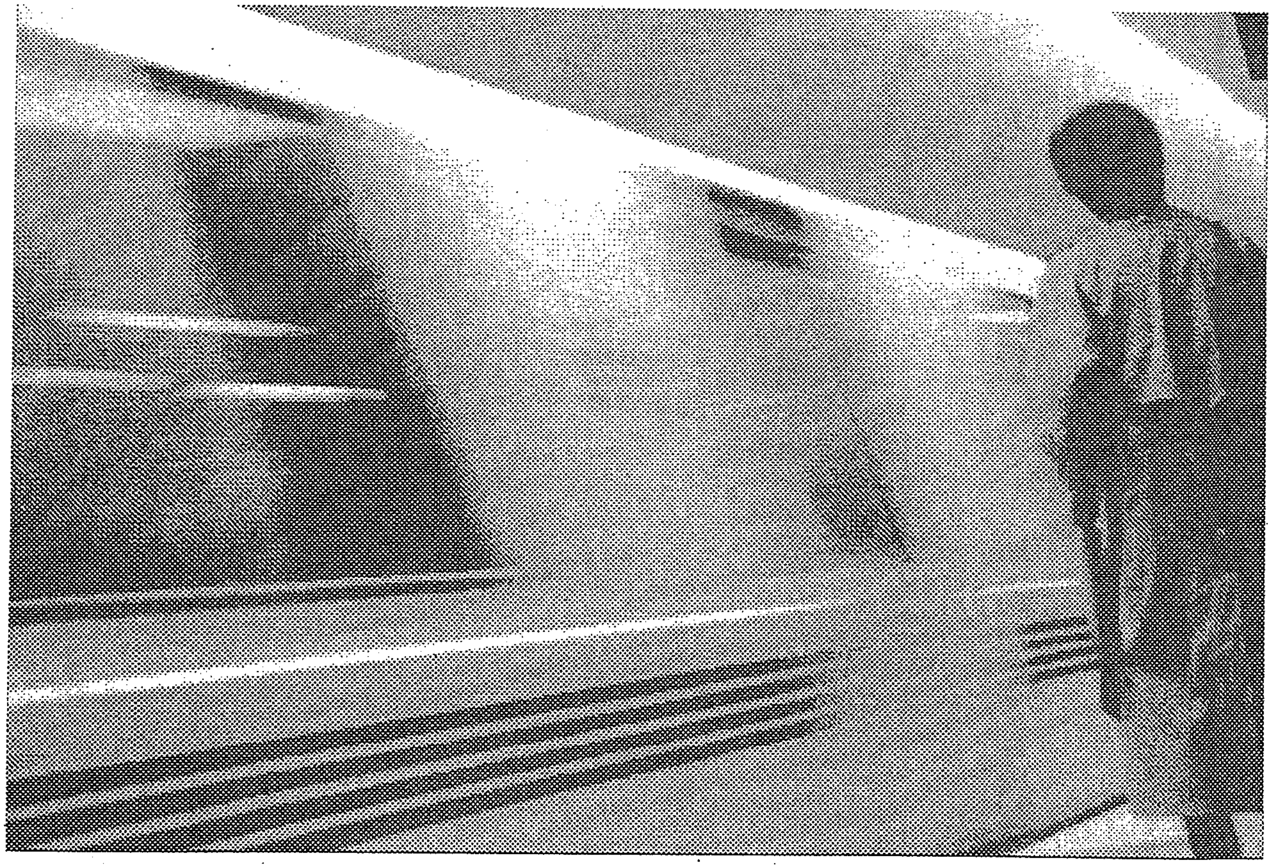
There are many reasons why BART's land use and development effects have to date been so modest. BART is essentially a commuter railroad, and the fact that most suburban BART stations are either surrounded by parking lots or in freeway medians has made nearby development difficult. In Berkeley, El Cerrito, and parts of San Francisco, neighborhood groups have long opposed more dense development around BART. Site assembly and financing difficulties combined with a lack of commercial demand have stifled station-area development along the Fremont line. BART has long insisted that new station-area developments provide free replacement parking, but that renders many projects economically infeasible. In short, the accessibility benefits from BART as capitalized into station-area land values have not been sufficient to overcome either weak local real estate markets or entrenched opposition to development.

Might things be different in the future? The success of the BART Rockridge station as well as recent evidence from Portland

FIGURE 7

BART station area retailer survey: advantages and disadvantages of near-BART locations

ADVANTAGES OF BEING LOCATED NEAR BART	Percentage of respondents answering	DISADVANTAGES OF BEING LOCATED NEAR BART	Percentage of respondents answering
Employee and customer convenience	43.2	Unwelcome people	32.2
More customers	38.7	Reduced safety and security	21.7
Greater visibility and exposure	20.0	Parking problems	13.0
More pedestrian traffic	14.8	Reduced sales volume	7.8
Near landmark	11.0	Lack of cleanliness	5.2
Easy and available parking	1.3	Congestion	5.2
Greater safety and security	1.3	Noise	2.6
Advertising	0.6	Image problems	0.9
None	12.9	None	30.4



indicate that there is a large untapped market for quality, mixed-use residential development within walking distance of regional rail transit. Successful experiences in metropolitan areas like Washington, D.C. and San Diego suggest that transit can be a catalyst to development where local governments, imaginative private developers, and transit agencies are able to work cooperatively together to overcome site assembly, design, financing, and entitlement barriers.

Overall, our findings confirm that the land use benefits from investments in rail transit are not automatic. Rail transit can contribute to positive change, but rarely creates change by itself. The hardware needs software—supportive land use policies such as density bonuses and ancillary infrastructure improvements—if it is to reap significant dividends.

BART is presently embarking on the largest expansion program in its history, with some 25 miles of suburban extensions at various stages of planning and completion. The degree to which Bay Area localities attempt to leverage BART's gift of improved accessibility will determine the land use effects of both existing and future investments over coming years. We trust there will be a BART@50 study to see if we are right. ◆

FURTHER READING

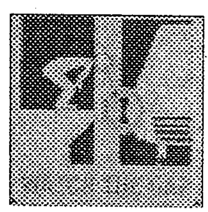
Blayney Associates/David M. Dornbusch & Co., Inc., *Land Use and Urban Development Impacts of BART* (San Francisco, CA: Metropolitan Transportation Commission, 1979).

Robert Cervero, "Rail Transit and Joint Development: Land Market Impacts in Washington, D.C. and Atlanta," *Journal of the American Planning Association* 60 (1): 83–90. 1993.

Robert Cervero and John Landis, "Twenty Years of BART: Land Use and Development Impacts," *Transportation Research* 31 (4): 309–333. 1996.

John Landis, Subrajit Guhathakurta, Ming Zhang, and William Huang, "Rail Transit Investments, Real Estate Values, and Land Use Change: A Comparative Analysis of Five California Rail Transit Systems," UC Transportation Center/ Berkeley Institute of Urban and Regional Development, Monograph 48. 1995.

Melvin Webber, "The BART Experience: What Have We Learned?" *The Public Interest* 45. 1976.



ATTACHMENT E

METROPOLITAN
TRANSPORTATION
COMMISSION

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Memorandum

TO: Transportation-Land Use Task Force Members DATE: July 19, 2004

FR: Valerie Knepper

RE: MTC TOD Study: Res. 3434 TOD Guiding Principles and Policy Approach Options

The purpose of this memo is to provide information regarding MTC staff's current thinking regarding "Guiding Principles" and to describe policy options to detail the MTC requirements for supportive land use policies for programming of Res. 3434 regional transit discretionary funds. Most importantly, the purpose of this item is for MTC staff and our consultants to receive feedback regarding the draft principles and policy options.

I. Draft TOD Guiding Principles

The following "TOD Guiding Principles" are intended to provide simple and clear statements that will guide our development of specific policies.

(a) Increase Transit Ridership By Encouraging Higher Density Development Around Stations. One of the key goals of the TOD policy is to increase transit ridership by providing more opportunities for people to live and work in close proximity to key transit stations and hubs. The TOD study will help MTC define minimum housing and employment densities that will maximize potential ridership, and thus cost-effectiveness, for new public transit investments funded under Resolution 3434.

(b) Ensure New Transit Villages are Livable and Vibrant Places. While generating transit ridership is a critical goal for any transit-oriented development policies MTC adopts, we are also looking to affirm that more compact development patterns and higher density residential and commercial growth around transit hubs bring with them livability, green spaces and other key quality-of-life features.

(c) Develop Criteria That Are Tailored. A key concept in defining "supportive land use policies" is to match the land use density and mix of uses to the ridership and access needs of specific transit modes (i.e., heavy rail, light rail, buses, ferries). In addition, policies must take into account the geographic diversity of the region and the variations in urban and suburban settings.

II. Policy Approaches for Defining "Supportive Land Use Policies" for Res. 3434

In December 2003, MTC adopted the policy that the programming of regional discretionary transit funds for Res. 3434 projects would require supportive land use policies by local jurisdictions. Indeed, the original Res. 3434 included a requirement for supportive land use policies. A major objective of the current TOD study is to develop an explicit and well-founded approach to implement this policy direction.

(a) Review of Existing Transit Oriented Development Policies
As a first step in this process, the TOD Study began by reviewing and summarizing policy approaches that support TOD development from both outside the region and from within the region. The consultants have developed a draft summary that reviews several important existing transit oriented development policies, and will provide a brief summary to you. In addition, they will discuss lessons learned from this review that appear relevant to the development of policies in the Bay Area.

(b) Conceptual Policy Approaches
Based on the guiding principles above and staff review of existing TOD policies, the following basic policy approaches can be considered. MTC staff anticipates including more than one policy option in the draft T-2030 (MTC's next regional transportation plan), to be released for public comment in the fall of 2004. (Please note that there are numerous and important variations and details needed to flesh out these approaches, which will be the subject of further discussions, but we are requesting your feedback on basic policy options at this point.)

1. Option 1: Transit Ridership Requirements
The most common approach by transit agencies to requirements for supportive land use policies has been to require that the station and/or corridor generate a target level of ridership. The level of ridership threshold and the limitations of other forms of access implicitly point to a level of needed density immediately around transit stations/hubs to satisfy the requirements/be highly ranked for this criterion. This basic approach, with important additional features, is used by the Federal Transit Administration for new transit starts using federal funds and by BART for achieving a recommendation to move forward into later stages of development. Given that land use development takes time, this approach may require progressively more concrete policy, regulatory and legal commitments by local jurisdictions to support achievement of the ridership levels.

2. Option 2: Density Requirements
Another approach is to directly require target levels of land use development matched to the needs of the proposed transit mode (i.e., heavy rail requires more ridership and thus would require higher levels of density than would light rail). This approach defines requirements closer to the control of local jurisdictions – i.e. land use planning and zoning controls. Density requirements can be defined in terms of residential density (e.g. 40 units an acre) or the number of people located around a station/corridor (e.g., 20,000 people within 1 mile). It can also be defined in term of residents only, or both residents and workers. As above, this approach may require progressively more concrete policy commitments by local jurisdictions over the timeline of the project.

3. Option 3: Point System Incorporating both Density and Design Requirements
Given that MTC has a strong commitment to improving the livability of our communities, and the positive influence of the design of places on walk and bike access to transit stations /hubs, another approach would be to include both targeted levels of density, (to be defined as per the discussion

above) and design requirements that facilitate non-auto access to transit stations/hubs. These factors would be combined into a point system that would reward both the level of development and also design features such as connecting streets and sidewalks, bike routes directly into stations, landscaping designed for pedestrians, and facilitation of pedestrian scaled retail and other activities.

4. Option 4: Matching Place Types and Mode

Different transit stations play different roles in the regional transit system, and while each station must generate sufficient use to be justified, and the entire corridor must generate sufficient use to be cost effective, the type of use may differ from station to station. These different patterns of use are termed "types" and include as basic types urban downtown, suburban center, and suburban village. Each of the types of transit modes (e.g. heavy rail, etc) interacts with each of the place types. For example, a heavy rail system in an urban downtown may have very high ridership levels by serving as an employment center, and may not have much residential use in the proximity. On the other hand, a light rail station in a suburban center may have high mixed use, while in a suburban village may have high residential densities. This approach would establish development requirements for types of transit and place type combinations.

We look forward to your input, ideas and recommendations.

Bay Area Transit Oriented Development (TOD) Study

Purpose, Key Questions and Study Approach

Study Purpose

The Transit Oriented Development (TOD) Study will assess the opportunities, benefits and barriers for increased levels of TOD in the San Francisco Bay Area, and help define MTC's policies in support of Bay Area TODs. Specifically, this study will recommend policies for conditioning regional discretionary funds under MTC's control for Resolution 3434 transit expansion projects on the demonstration of supportive land use policies by local government around transit stations and along key transit corridors. This direction was adopted in principle as part of Resolution 3434 and reaffirmed in the Commission's approval of the draft five-point transportation-land use platform in December 2003. This study will play an instrumental role in defining and implementing this policy, and will be conducted in close partnership with ABAG, transit agencies, local governments and other interested stakeholders.

Key Questions and Study Approach

The following key questions will be addressed in the study:

Question 1 - How much opportunity for TOD exists in the Bay Area, what kinds of opportunities are there, and where are they? What does the best-case scenario for TOD look like regionally? What different types of opportunities for TOD are there in the region?

- *Work with ABAG to estimate the potential regional size and impact of TOD in the Bay Area. Summarize current, future and "best case TOD" conditions next to transit stations and in transit corridors in the Bay Area, including demographics, land use conditions, local policies, and transit ridership impacts. Identify types of TOD opportunities in the Bay Area by transit mode and other characteristics.*

Question 2 – What policies to support transit oriented development are being used in other areas of the country, as well as within the Bay Area?

- *Summarize regional policies to support TODs, including different regional policy approaches and incentive programs from outside the Bay Area, and relevant policies from within the region.*

Question 3 – What are the components of an effective regional policy to support TOD in the Bay Area?

- *Assess the lessons learned from other regions and from within the Bay Area.*
- *Assess the existing transportation and land use planning processes within our region, and the unique characteristics and diversity of the Bay Area.*
- *Propose policy planning approaches that more closely link regional transit investments with corresponding levels of local land use development policies.*

Question 4 – How do we test and evaluate the potential policy approaches as proposed?

- *Develop and review the proposed approach with technical advisors, policy advisors, and the public.*
- *Conduct case studies with local jurisdictions to analyze the effectiveness of the proposed policies in detail. Refine the policy approach based on partner feedback and further analysis.*
- *Refine the policies based on the feedback and findings from the case studies.*

Question 5 – What is the objective of the TOD Study?

- *Recommend policies for conditioning regional discretionary funds under MTC's control for Resolution 3434 transit expansion projects on the demonstration of supportive land use policies by local government around transit stations and along key transit corridors.*

BAY AREA TRANSIT ORIENTED DEVELOPMENT (TOD) STUDY

PROJECT SCHEDULE (abbreviated)

Task #	Task Description	Completion Date
1	Refined project scope and schedule	June 1, 2004
2	Summary of policy approaches/ incentive programs from outside and within the Bay Area to support TODs. Lessons learned relevant to MTC policy development.	June 18, 2004
3	Analyses of land use and demographics (current, future and "best case TOD") conditions and plans proximate to transit stations/hubs/corridors • Population, household and employment information in the areas immediately proximate to current and future transit stations, hubs and corridors for existing, forecast future, and "Best Case TOD" scenarios • Planned land use from local General Plans proximate to transit	August 30, 2004
4	Types of Bay Area TOD opportunities and relevance to development of policies • Types of Bay Area TOD opportunities, distribution of TOD opportunity types, and the relevance to the development of MTC policies. • Issues and opportunities relevant to each type of TOD opportunity, and implications for supportive regional policies. • Regional market conditions for development in transit corridors / stations of the regional "Best Case TOD" scenario. • Estimate of regional transit ridership impacts of the "Best Case TOD"	July 30, 2004
5	Overall regional policy approaches to support matched development of land use and transportation • Potential policy approaches including incentives and performance measures. • Potential performance measures for minimum densities and intensities for the programming of transit expansion funds under MTC's Resolution 3434 on supportive land use policies by local jurisdictions. • Effective approaches for achieving supportive local land use policies.	August 27, 2004
6	Case studies analyses. For each location: • Existing conditions and current plans, report on site tour and discussions with local planners and interests • Summaries of opportunities, including the market assessment and land use potential. • Summaries of the relative ridership estimates from TOD. • Recommended solutions or approaches to address any impediments to development of TOD • Recommending refinements to MTC's policy approach.	April 30, 2005
7	Final Report, PowerPoint presentation, Briefing Book	June 1, 2005

ATTACHMENT 3b-1

Transportation and Land Use Policy Platform

1. **Develop a transportation/land use policy statement for the Transportation 2030 Plan.**
   - Develop a clear transportation/land use policy statement that provides a framework for evaluating the land use implications of major project and program choices in the Transportation 2030 Plan.
   - Focus on assessing transportation projects and programs specifically, as a complement to the other elements of the Smart Growth Project recommendations dealing with housing, open space preservation, socio-economic location/displacement.
   - Develop in cooperation with transportation, regional, and local government partners.

2. **Determine an appropriate percentage of TLC/HIP program that should fund specific plan development around existing or near-term future rail stations or corridors.**
   - Complement discreet, community/neighborhood scale improvement projects of the TLC/HIP program with broader land use strategies.
   - In partnership with ABAG's corridor planning initiative, enhance the potential for transit oriented development by providing financial support of specific plans detailing developable parcels, zoning requirements and mitigation hazards in areas around transit stations or along transit corridors.

3. **Encourage changes to local general plans that support Transit Oriented Development for Resolution 3434 investments.**
   - Promote development of land uses adjacent to major transit extensions, to support ridership markets that will make these investments economically feasible.
   - Condition the award of regional discretionary funds under MTC's control for Resolution 3434 expansion projects, on the demonstration by local government that plans are in place supporting some level of increased housing/employment/mixed use density around transit stations/transfer centers.

4. **Support transportation/land use coordination beyond transit corridors.**
   - Continue to pursue neighborhood scale access improvements (bike/pedestrian/local transit) outside of the rail/major transit corridor network, highlighted through the TLC program.
   - In conjunction with ABAG, develop a housing location strategy in tandem with a jobs location/economic development strategy, to recognize the synergistic commute relationships between the two.
   - Develop a regional open space strategy, in conjunction with ABAG, which would reinforce infill development as a priority for growth in cities and established suburbs.

5. **Coordinate transportation/land use issues with regional neighbors**
   - Pursue cooperative planning with neighboring regions to the north (SACOG region and Lake and Mendocino counties), east (San Joaquin and Stanislaus counties) and south (San Benito, Monterey and Santa Cruz counties) of the Bay Area.
   - Identify and resolve data gaps or inconsistencies in long range demographic forecasts (what are these regions projecting for future jobs and housing?), as well as travel projections on key transportation facilities connecting the MTC region to its neighbors—I-80, I-580, US 101-North; US 101- South, State Hwy 17 and State Hwy 1.

EXHIBIT 18

C.V. of Terry Watt

Terrell Watt, AICP
Terrell Watt Planning Consultants
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EXPERIENCE

1989 -	**TERRELL WATT PLANNING CONSULTANTS** Planning consulting firm owner
1981-1989	**SHUTE, MIHALY & WEINBERGER** Planning Expert/Paralegal
1981-1983	**MUNDIE & ASSOCIATES** Planning Consultant to public and private clients
1979-1980	**EDAW, INC.** Project Management, Planning Consultant

PROFESSIONAL MEMBERSHIPS AND BOARDS

American Institute of Certified Planners (AICP)
American Planning Association (APA)
Board Member of the Conservation Biology Institute www.consbio.org

EDUCATION

USC GRADUATE SCHOOL OF URBAN AND REGIONAL PLANNING
Masters degree in City and Regional Planning

STANFORD UNIVERSITY
Bachelor's degree in Urban Studies

Since 1989, Terrell Watt, AICP, has owned Terrell Watt Planning Consultants. Ms. Watt's firm specializes in planning and implementation efforts focused on regionally-significant projects that promote sustainable development patterns. Prior to forming her own consulting group, she was the staff planning expert with the environmental and land use law firm Shute, Mihaly & Weinberger. She is an expert in general and specific planning, open space and agricultural land conservation and environmental compliance. Her skills also include public outreach, negotiation and facilitation.

Terrell works with a wide variety of clients throughout California including conservation organizations, government agencies and foundations. Her recent projects include:

- Project Coordinator for the Los Angeles Infill Potential Methodology study, funded by an Environmental Justice Grant from Caltrans and jointly sponsored by the City of Los Angeles, County of Los Angeles and Environment Now.

- Secretary Terry Tamminen's Representative to the California Infill Study Task Force, a Subcommittee to the State's Smart Growth Task Force.

- Primary consultant to the City of Livermore on the South Livermore Wine County Specific Plan and Transfer of Development Rights Program.

- Consultant to the Institute of Local Self Government for the development of A Local Official's Guide to Funding Open Space Acquisition.

- Consultant to the Planning and Conservation League led coalition of community and environmental groups on California High Speed Rail.

- Member of Mayor Gonzales' San Jose Coyote Valley Task Force on behalf of the Silicon Valley Conservation Council.

- Founder and Project Director of the newly forming Association of Infill Builders.

SUMMARY OF RECENT PROJECTS

South Livermore Valley Wine Country General Plan Amendment, Urban Growth Boundary, Specific Plan and Transfer of Development Rights projects. Assisted the City of Livermore in developing and adopting the South Livermore Valley Wine Country plan and implementing documents. The results include one of the highest per unit/per acre agricultural and open space mitigation fees in California, limited "final" urban development forming a permanent urban growth boundary and protection of over $5,000 acres of prime agricultural and habitat land.

Santa Clara County Parks and Recreation Department: Assisted 2M Associates to prepare the Department's Strategic Plan for parks and open space development and protection. The Strategic Plan includes proposals for renewing the Park Charter fee for open space.

Planning and Conservation League: Coordinating comments from an informal network of environmental and conservation organizations on the proposed High Speed Rail project and related environmental review document (EIR/EIS). Funding is provided by the Resources Legacy Fund Foundation.

San Francisco Public Utilities Commission/Jones and Stokes Associates: Assisting with the community outreach program and the preparation of a Habitat Conservation Plan for the Alameda Watershed.

Caltrans, City of Los Angeles, County of Los Angeles and Environment Now: Coordinator of the Los Angeles Infill Working Group, which is tasked with preparing a report on infill potential and strategies for infill projects under an Environmental Justice Grant from Caltrans.

Mid-Peninsula Regional Open Space District: Assisted in the development of a service plan, LAFCo applications and environmental documents for the District's annexation of the San Mateo Coast.

The Nature Conservancy, California: Assisting TNC to develop conservation priorities and an Oak Woodland Protection program for Tulare County.

Infill Builders Association: Assisting a number of builder organizations and non-profits to form an Association to advance infill development in California.

Institute for Local Self Government (ILSG)/Local Government Commission: Assisting in the preparation of a guide for local governments on funding mechanisms for open space protection. Funding for the report is provided by the Resources Legacy Fund Foundation and the David and Lucile Packard Foundation.

Cambria Services District and Local Coalition: Prepared a toolbox of funding mechanisms and organizational options for protecting open space.

Open Space Fee Agreements with Landowners: Transfer tax for open space on new residential/resort development in Truckee and Placer County; Mello-Roos assessment on new residential and commercial development in Fairfield; agricultural conversion fees and dedication requirements in South Livermore; land dedications in return for development on the Newport Coast; Orange County NCCP/HCP fees.

Proposition 218 Campaign in Santa Clara County: Led the Silicon Valley Conservation Council effort to pass a Proposition 218 benefit assessment fee for open space funding in Santa Clara County.

Caltrans, The Nature Conservancy and Green Info Network: Assisted the team to evaluate how best to coordinate resource conservation and transportation planning. Work products include a computer application that illustrates potential conflicts between proposed transportation projects and TNC portfolio sites and a report outlining the transportation process in California.

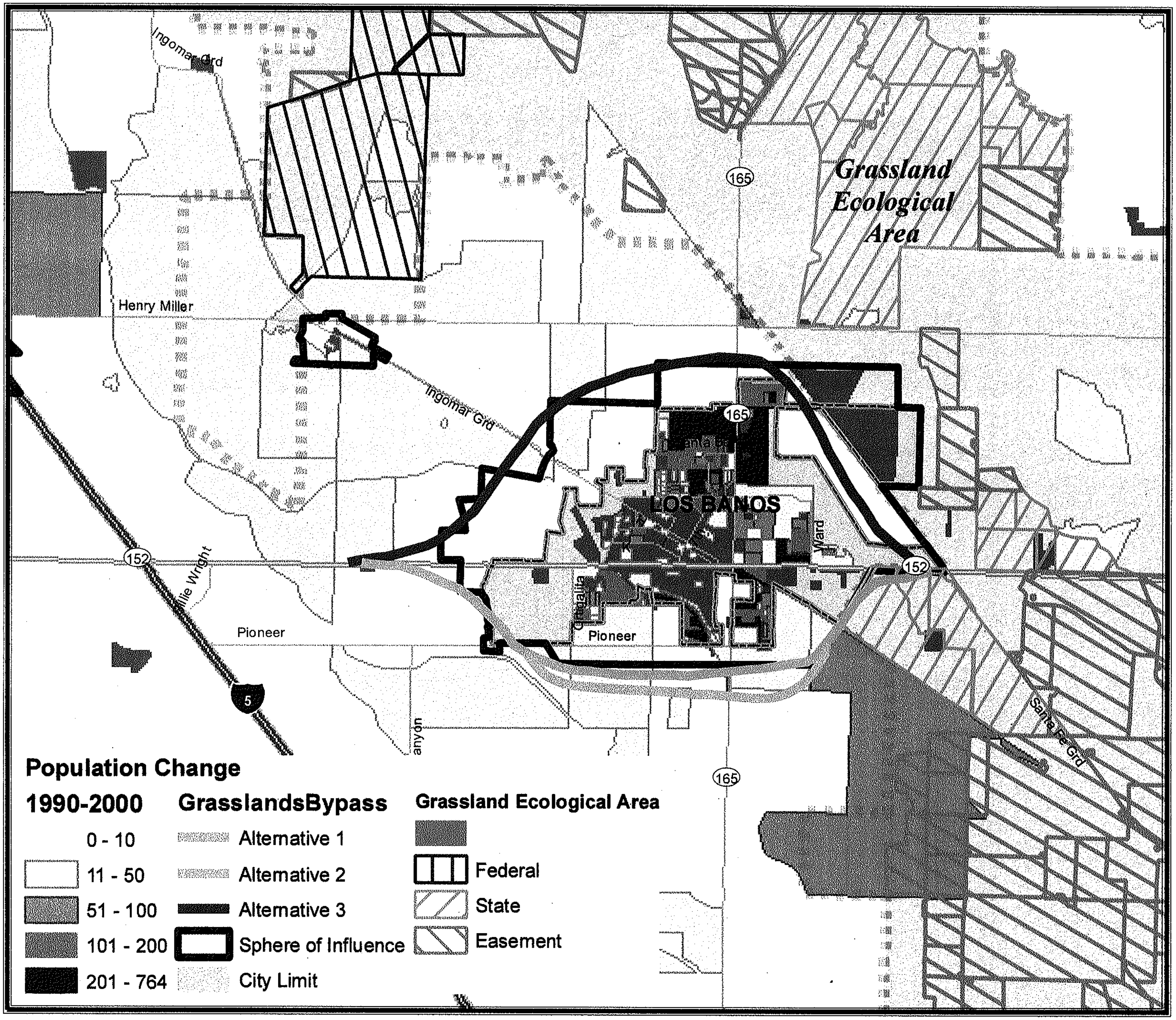
Tejon Ranch Working Group/Environment Now Foundation: Coordinator of the Working Group to determine and advance the importance of protecting high value resources on the Tejon Ranch through comprehensive planning.

Sierra Watch: Planning consultant to Sierra Watch, a non-profit directed at sensible planning for the Sierra.

Humboldt County Watershed Council. Working with the Council and five other leading environmental groups to ensure that conservation policies are included in the Humboldt County General Plan update, which is currently underway. Funded is provided by the Resources Legacy Fund Foundation.

EXHIBIT 19

Map of Los Banos Area Growth Patterns in relation to GEA Boundary, Federal and State Lands, and Federal and State Easements



Ingomar Grd
Henry Miller
Grassland Ecological Area
165
Ingomar Grd
LOS BANOS
Ward
152
Willie Wright
Pioneer
Ortigalita
Pioneer
5
anyon
Santa Fe Grd
165
Population Change
1990-2000
0 - 10
11 - 50
51 - 100
101 - 200
201 - 764
GrasslandsBypass
Alternative 1
Alternative 2
Alternative 3
Sphere of Influence
City Limit
Grassland Ecological Area
Federal
State
Easement